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ESSENTIALS OF HISTOLOGY

BY

LOUIS LEROY, B.S., M.D.

Professor of Histology and Pathology in Vanderbilt University, Medical and
Dental Departments; Bacteriologist to the State of Tennessee;
Pathologist to Nashville City Hospital; Associate Editor
"Medical Examiner and Practitioner," etc.

ARRANGED WITH QUESTIONS FOLLOWING
EACH CHAPTER

92 ILLUSTRATIONS

Second Edition, Revised and Enlarged

PHILADELPHIA, NEW YORK, LONDON
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1903

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This small volume is affectionately dedicated to my Father,
CHARLES L. A. LEROY

PREFACE TO THE SECOND EDITION

THE first edition of this work having been exhausted in a comparatively short time, it has not been deemed necessary to make any very extensive alterations in the text. A number of new original illustrations have been inserted, mostly photomicrographs, where it has seemed that additional clearness might result. The chapter on Technic has been somewhat enlarged, a description of the appendix and rectal valves added, and various small corrections made and details inserted. The author wishes to acknowledge his thankfulness to the profession for their generally favorable reception of the first edition, and again to call attention to the fact that the work is intended not as an exhaustive treatise, but solely as an "Essentials" of Histology.

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PREFACE.

THE main intention in writing this work has been to collect within a limited space and in a convenient form the essential facts in histology. At the same time the author has endeavored not to sacrifice clearness and intelligibility to the necessarily great condensation. It is hoped that the work may find a field of usefulness among graduates who have been some time away from the histologic laboratory, and become a trifle "rusty;" among men who, having graduated at a time when the subject was not taught in most of the colleges, desire to acquire in a short time sufficient knowledge of histology to enable them understandingly to read pathology; and especially among students, to save them much of the inconvenience of taking voluminous notes, which always, to a greater or less extent, hampers a man and often causes him to lose some of the most important points in the endeavor to make a note of some trivial detail.

Thanks are herewith tendered to my head assistants, R. H. Hough and F. B. Wilson, for their valuable aid —to the former, for the preparation of most of the illustrations from original sketches by the author; to the latter, for the arrangement of the manuscript and the preparation of many of the specimens from which the illustrations were made.

NASHVILLE, TENN., *September, 1900.*

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HISTOLOGY.

CHAPTER I.

HISTOLOGY is the microscopic science of normal tissues. No matter how carefully we dissect the various tissues or organs of the body, we can with the unaided eye obtain but little knowledge of their ultimate composition. An examination of the smallest portion of muscle, cartilage or bone, for instance, will reveal nothing which could not be seen in a gross specimen. The moment, however, we bring the microscope to bear upon any organ, an astonishing complexity of structure is revealed. The whole field of view is seen to be composed of minute bodies, differing greatly in appearance from the tissues they compose, and arranged in more or less definite order. These small bodies have received the name of cells, and are the histologic units.

CELLS.

A cell is a microscopic, protoplasmic mass, which, when typical or complete, contains cell-wall, cell-body, nucleus, nucleolus, and centrosome.

Some cells lack one or more of the above, and are said to be atypical or not complete—*e. g.*, the red corpuscle contains usually neither nucleus, nucleolus, nor centrosome. The loss of these constituents can usually be traced to some stage of development.

Cell-body.—The cell-body, protoplasm, or cytoplasm, as its name implies, constitutes the largest part of the cell. It is surrounded by the cell-wall, and incloses the nucleus, nucleolus, and centrosome. The relative size and the internal structure of the cell-body vary greatly according to the locality from which the cell is taken. When examined under a high magnification, the cell-body is seen to consist of a network or reticulum of exquisitely delicate fibers (the *spongioplasm*), the interstices of which are filled with a transparent, homogeneous substance (the *hyaloplasm*). Besides these two substances, we usually find some small granules embedded in the hyaloplasm. These are usually believed to be not a part of the cell, but rather the result of some vital change in the cell-substance, or in some cases to be partially assimilated substances from without. These granules have received the special name of *metaplasm* or *microsomes*.

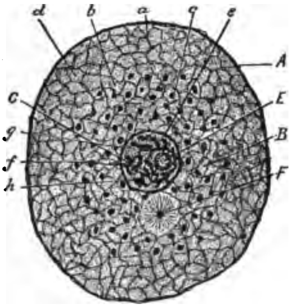

Fig. 1.—Diagram of a typical cell: *A*, Cell-wall; *B*, cell-body; *C*, nucleus; *E*, nucleolus; *F*, centrosome; *a*, spongioplasm; *b*, hyaloplasm; *c*, metaplasm or microsomes; *d*, exoplasm; *e*, nuclear membrane; *f*, nuclear network or chromatin filaments; *g*, nuclear matrix; *h*, nodal enlargements or net knots.

At the outer edge of the cell-body there is usually a narrow zone which is free from microsomes, and which has received the distinguishing name of *exoplasm*.

Cell-wall.—The cell-wall is a delicate, structureless membrane enveloping the cell, and is derived from the cell-body.

Nucleus.—The nucleus is an easily discernible, highly refracting body lying within the cell. It is quite complex in structure. Under a high magnification we are able to distinguish—

(*a*) *Nuclear Membrane.*—A very thin membrane surrounding the nucleus (sometimes absent).

(*b*) *Nuclear Network.*—A network of fine, strongly staining threads or filaments called chromatic filaments. These filaments exhibit along their course, and also at their points of intersection, certain thickenings called nodal enlargements or net knots.

(*c*) *Nuclear Matrix.*—A transparent, gelatinous, semifluid substance which occupies the space between the fibrils and the nuclear network.

Nucleolus.—The nucleolus (plural, *nucleoli*) is a small spheric body usually lying in the nuclear network. There may be several of these bodies in a single cell.

Centrosome.—The centrosome is a very minute body usually situated in the nucleus and surrounded by a small clear area. During cell-division, however, it is found in the cell-body. Radiating from the centrosome to the chromatin filaments are found a number of straight lines, which are extremely fine and very difficult to see.

The nucleus seems to be the part of the cell which contains and transmits the hereditary characteristics. The centrosome apparently controls the reproduction of the cell.

Properties of the Cell.—As the body is but a collection of cells and intercellular substance, it is natural for us to expect to find the cell possessing certain attributes which characterize a living organism. Among these properties may be named—

Metabolism—absorbing nutrition and excreting waste.

Growth.

Reproduction.

Irritability—response to stimulation.

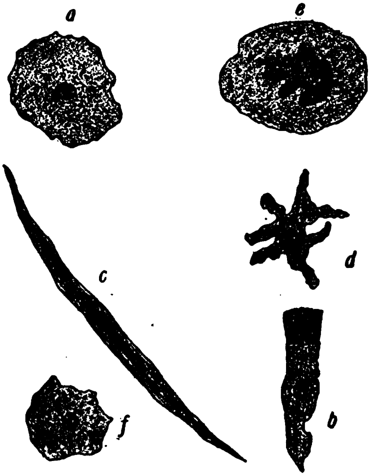

Fig. 2.—Cells from various localities: *a*, Squamous epithelial cell from tongue; *b*, ciliated epithelial cell from trachea; *c*, smooth muscle-cell from uterus; *d*, pigment cell from choroid coat of eye; *e*, eosinophile cell from blood; *f*, cell from liver.

Motion—in some cells from place to place, in others simply the extension and retraction of the cell-body.

Function.—All normal cells have a certain life-work to perform, which is called their function.

Origin of Cell.—All cells originate from a preexisting cell, and can not be generated spontaneously.

Modes of Cell-division.—Two modes of cell-division are known—(1) *direct division* or *budding;* (2) *indirect division, karyokinesis, mitosis,* or *karyomitosis.*

Direct Division.—In the process of direct division a constriction occurs in the center of the cell which increases until the cell is split in two.

Mitosis.—The process of indirect division is by far the more frequent and complicated method. The process is chiefly concerned in the nucleus, and has been divided into stages for the sake of convenience of description, although, of course, in reality they merge imperceptibly from one into the other.

Resting Stage.—In this stage the cell is, as has been described, above the chromatin filaments, being arranged in a network.

Close Skein.—The centrosome leaves the nucleus and divides into halves, which proceed to opposite poles of the cell and, together with their radiating lines and clear zone, are called attraction spheres. The nuclear network resolves itself into a fine close skein.

Loose Skein, or Wreath.—The skein becomes less tangled and more distinct. It then resolves itself into a number of convolutions arranged as a wreath. (See Fig. 3.)

Monaster.—The loops of the wreath separate, leaving a series of V-shaped threads with the apex of the V toward the center of the cell, giving a radiating or star-form, hence the name.

Diaster.—Each V shape in the monaster now splits horizontally into exactly similar halves whose apices begin to diverge from their respective opposite halves and point toward the nearest attractive sphere.

In this condition they present the appearance of two stars, each consisting of half the monaster, called daughter stars.

Division of Nucleus.—These daughter stars separate from each other, going toward the attraction sphere, and the sides of the nucleus begin to constrict at a zone between the daughter stars. This constriction progresses until we have the nucleus divided into two. Each half contains a daughter star and an attraction sphere.

Division of Cell-body.—The cell-wall next assumes an indentation, which increases in size until the cell is divided in two, a half of the original nucleus remaining in each half cell.

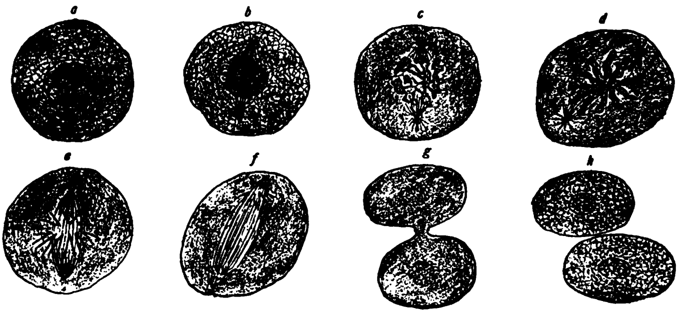

Fig. 3.—Diagram of stages of karyokinesis: *a*, Resting stage; *b*, close skein stage; *c*, *d*, loose skein or wreath stage; *e*, monaster stage; *f*, diaster stage; *g*, showing constriction of cell-body and two nuclei in loose skein; *h*, cell divided completely, nuclei in resting stage.

Reverse Procedure.—The chromatin fibrils in the daughter stars now begin to undergo a reversed procedure.

The ends of the V-shaped fibers unite to form a wreath which tangles to become a *close skein*, which relapses into the *nuclear network* found in the resting stage. The nucleoli reappear.

The attraction sphere once more enters the nucleus, and we have two cells, which are identical (except in size) with the parent cell.

Time Required.—These changes, while complex, take place rapidly. In the human subject half an hour may be sufficient to complete the cycle.

Development.—It has been stated above that cells are always produced by preexisting cells. This would lead us to suspect that the origin of the adult animal might be traced backward to a single cell.

Ovum.—In man this origin may be traced to the *ovum*, a complete or typical cell generated in the ovary of the female. This cell passes down one of the Fallopian tubes to the uterus, meeting and uniting, on the way down, with a spermatozoon (the male element), provided conception has occurred.

In the uterus it multiplies by indirect division into two, these two into four, then into eight, etc. For some time this process is kept up, the cells arranging themselves to form a spheric mass, which has been termed the mulberry mass.

Multiplication of some groups of cells now proceeding faster than others, the mass begins to flatten and lengthen, and eventually arranges itself into three superimposed layers, called the primary germ layers.

Primary Germ Layers.—The upper layer is called the *epiblast*, or *ectoderm ;* the middle layer is called the *mesoblast*, or *mesoderm ;* the lower layer, the *hypoblast*, or *entoderm*. To these some writers have added a fourth layer, the *parablast*.

Specialization.—The cells of these layers in their growth now begin to assume certain characteristic peculiarities, which differentiate them more and more and cause them to resemble the various tissues they are to form. This process of specialization proceeds in a regular and definite form, the same layer always producing the same structure in the adult.

Tissue.—A tissue is an aggregation of similar cells and intercellular substance having a common function. The principal tissues originating from the primary germ layers are as follow (from Piersol):

From the *epiblast*, or *ectoderm*, are derived the epithelium of the outer surface of the body, including that of the conjunctiva and of the anterior surface of the cornea, the external auditory canal, together with the epithelial appendage of the skin, as hair, nails, sebaceous and sweat-glands.

The epithelium of the nasal tract, with its glands and communicating cavities.

The epithelium of the mouth, and salivary and other glands discharging into the oral cavity.

The enamel of the teeth.

Tissues of the nervous system.

The retina of the eye.

The epithelium of the membranous labyrinth.

The pituitary and pineal bodies.

From the *mesoblast:*

The connective tissues.

Areola tissue.

Tendons.

Cartilage and bone.

Dentin of teeth.

The muscular tissue (except that of sweat-glands).

The tissue of the vascular and lymphatic systems, with their endothelium and circulating cells.

The sexual glands and their excretory passages as far as the termination of the ejaculatory ducts, the vagina, the kidneys, and ureter.

From the *hypoblast*, or *entoderm:*

The epithelium of the digestive tract, with that of all the glandular appendage, with the exception of those named as being of epiblastic origin. The epithelium of the respiratory tract.

The epithelium of urinary bladder and urethra.

The epithelium of thyroid and thymus bodies (in the latter, Hassel's corpuscles).

If we consider the *parablast* as one of the germ layers, we must omit certain structures from the above classification, as follows :

Tissue developed from parablast.

Blood-vessels.

Lymphatics and lymph-glands.

Blood-corpuscles.

Connective tissue.

All the tissues of the body may, for convenience, be divided or classified into five groups—viz.: (1) Epithelial tissue ; (2) connective tissue ; (3) muscular tissue ; (4) nervous tissue ; (5) fluid tissues.

The Connective Tissue.—The principal connective tissues are—mucous, white fibrous, yellow elastic, adipose, retiform, cartilage, bone, and dentin.

Areola tissue is a tissue composed of white fibrous, yellow elastic, and adipose tissues in varying amounts.

Mucous tissue is composed of large branching cells surrounded by a soft gelatinous substance (mucin). In the adult it is found in the vitreous humor of the eye. In the embryo it occurs in the umbilical cord and in the subcutaneous tissue.

White fibrous tissue is made up of very fine, delicate fibrils, which run more or less parallel, do not branch, and are united to form bundles. These bundles may unite to form larger bundles, or may cross to form a regular network. Two kinds of cells are found in this tissue—known as the *wandering* and the *fixed* cells. The fixed cells are irregularly stellate, and are direct descendants of the mesoblastic cells. It is through the agency of these cells that the fibers are formed. The wandering, or migratory, cells are originally white blood-corpuscles that have wandered into the tissue by virtue of their ameboid motion. When boiled, white fibrous tissue yields gelatin. This tissue is found in a great variety of locations, being probably the tissue most frequently met with in the body, serving as it does to form a framework for all the organs, to bind individual fibers of muscles and nerves, and as a support to blood-vessels, lymphatics, and nerves.

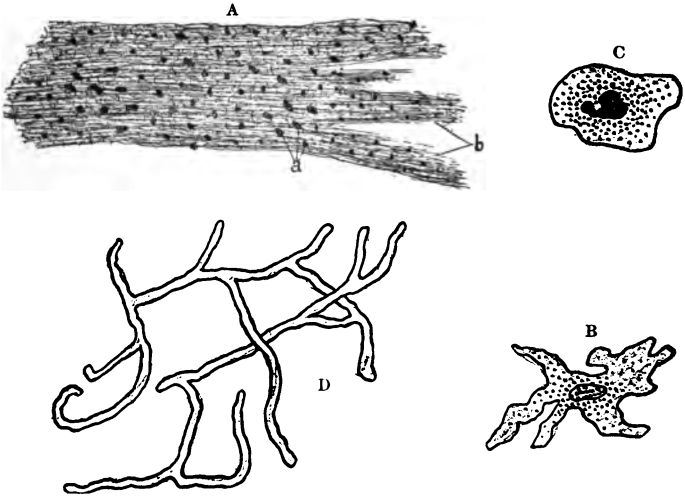

Fig. 4.—A, White fibrous tissue; *a*, nuclei of fixed and wandering connective-tissue cells; *b*, ends of white fibers; B, isolated fixed connective-tissue cell, highly magnified; C, wandering, or migratory, connective-tissue cell, highly magnified; D, yellow elastic tissue, very highly magnified.

Tendons.—The tendons are strong fibrous cords serving to unite muscle to bone. These cords are made up of numbers of bundles of dense white fibrous tissue, called *secondary bundles,* and are continuous with the fibrous investment of the muscular fibers, which are bound together by circularly disposed bands of areola tissue. Each bundle of fibers can be subdivided into smaller bundles of very delicate fibrillæ, called *primary bundles.* Between these primary bundles are numbers of large irregularly branched *tendon cells,* whose processes extend around and are firmly applied to the sides of the adjoining bundles, thereby aiding in holding them together. Blood-vessels and occasionally a small nerve-fiber are found in the areola tissue surrounding the secondary bundles.

Yellow elastic tissue consists of branching fibers that form an elastic network in various locations. The fibers are under some tension, and when broken tend to curl up at the ends. This tissue usually occurs associated with others of the connective-tissue group, as, for instance, in areola tissue. It may, however, be found nearly free from other admixtures in the ligamentum nuchæ or in the subflava, in which case the fibers are much thicker and larger than in other localities. It occurs in considerable amount in the subcutaneous tissue, arteries, lungs, capsules of organs, and in the mesentery, omentum, and other serous membranes.

Adipose tissue is composed of large, clear, poorly stained spheroid cells, known as fat-cells, supported by white fibrous tissue. The fat-cells are derived from the fixed connective-tissue cells by a change of the protoplasm into an oily substance and the probable absorption of additional substances from without. During this process the irregular cell-wall of the fixed connective-tissue cell is distended until it assumes a spheric shape, the nucleus meanwhile being pushed to one side of the cell. Under adverse circumstances, as in starvation, the fat-cell may return to its original form. Crystals of fatty acid (margarin) are frequently seen in adipose tissue. This tissue occurs in varying amounts in areola tissue under the skin, between muscles, and surrounding nearly all the viscera with the exception of the brain and spinal cord.

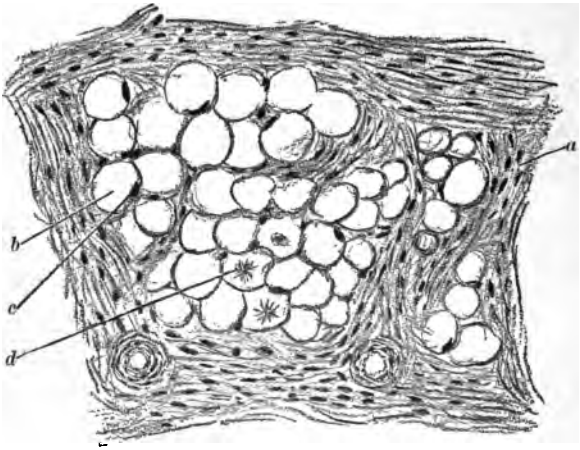

Fig. 5.—Adipose tissue: *a*, Fibrous tissue; *b*, fat-cells; *c*, nucleus of fat-cells; *d*, fatty acid crystals in fat-cells.

Retiform tissue consists of a fine reticulum of fibrous tissue. The fibers are usually closely enveloped by flat, irregular, connective-tissue cells.

Adenoid tissue is retiform tissue that has entangled in its meshes numbers of small, round, lymphoid cells.

CARTILAGE.

There are three main varieties of cartilage—viz.: Hyaline, yellow elastic, and white fibrous. A fourth variety, cellular, is sometimes mentioned, but it is not found in man.

All varieties are surrounded by a fibrocellular membrane called *perichondrium*. This membrane is divided into an outer part, or *fibrous layer*, in which white fibrous tissue preponderates, and an inner, or *cellular, layer*, in which the connective-tissue cells occur in great numbers. These two layers merge insensibly into one another.

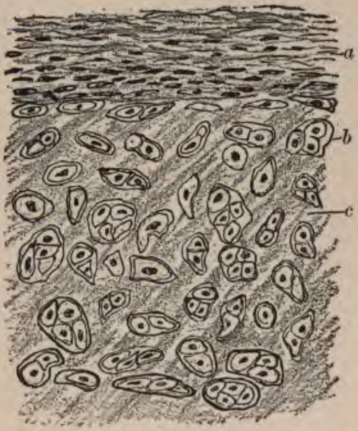

Fig. 6.—Hyaline cartilage: *a*, **Perichondrium;** *b*, **group of cartilage-cells;** *c*, **hyaline matrix.**

Hyaline cartilage is composed of a firm, translucent, bluish, opalescent substance called *matrix*, or *ground substance*.

This matrix, or ground substance, under ordinary means of observation appears to be entirely homogeneous, but by special methods of preparation it may be resolved into very fine fibers united by a cement substance. Scattered loosely through the matrix are found small spaces called *lacunæ.*

The portion of the matrix immediately surrounding the lacunæ is denser than usual and is called the *capsule.*

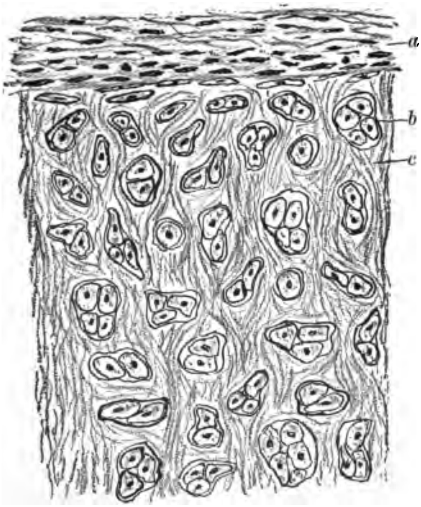

Fig. 7.—White fibrocartilage: *a*, Perichondrium; *b*, group of cartilage-cells; *c*, white fibrous fibers and matrix.

Within the lacunæ lie the *cartilage-cells,* which are but specialized connective-tissue cells, the descendants of the cells in the lower layer of the perichondrium. They are large cells with granular nuclei and relatively good-sized cell-bodies, which frequently contain vacuoles. As neither blood-vessels nor lymphatics have been positively demonstrated in human cartilage, its mode of nutrition is still a problem. Some of the lower animals, however, have minute channels, called canaliculi, connecting the lacunæ and conveying lymph to the cells; reasoning by analogy, it is plausible to believe that such canaliculi may exist undemonstrated as yet in the human tissue. Hyaline cartilage occurs in many localities where a strong yet flexible and resistent tissue is required—*e. g.*, articular cartilage, costal cartilage, trachea and bronchi, the Eustachian tube, and nose; in the embryo it is the progenitor of the entire osseous system, with the exception of some of the flat and irregular bones of the skull.

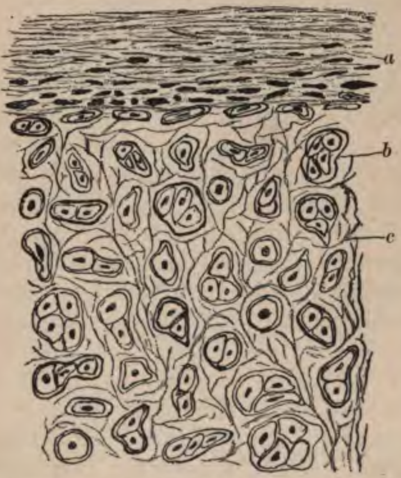

Fig. 8.—Yellow elastic cartilage: *a*, Perichondrium; *b*, group of cartilage-cells; *c*, yellow elastic fibers in stroma.

White fibrous cartilage is essentially a hyaline cartilage that has numerous bundles of white fibrous tissue coursing in all directions through its matrix. The cells are usually more sparsely distributed and the capsule denser than in the hyaline variety. These characteristics adapt the fibrous cartilage particularly to locations where great tensile strength combined with flexibility is required. Hence, we find it in the symphysis pubis, the intervertebral discs, the sternoclavicular and temporomaxillary articulations.

Yellow elastic cartilage, or **reticular cartilage,** resembles hyaline cartilage in all respects save that it has in addition a network of yellow elastic fibers within its matrix. These fibers, as a rule, do not envelop the lacunæ very closely, but leave clear areas around them, within which the cells can be easily seen. This addition of elastic fibers produces a tissue that is pliable yet elastic. We find such tissue of special advantage in such localities as the external ear, the epiglottis, the arytenoid cartilage, and cartilage of Santorini or of Wrisberg.

Cellular cartilage does not occur in the human subject, but may be found in some of the lower animals —*e. g.*, the ear of rats and mice. It consists of very numerous and closely aggregated cartilage-cells that have no matrix proper surrounding them, but are retained in position by an intercellular cement substance.

In old age, deposits of calcium salts may be found in any of the cartilages; when so found, the cartilage is said to be calcified. By the action of prolonged boiling, chondrin can be extracted from the cartilage.

QUESTIONS FOR CHAPTER I.

1. What is histology?
2. What is a cell?
3. What structures does a typical cell contain?
4. What are the cell-body? spongioplasm? hyaloplasm? exoplasm?
5. What is the cell-wall?
6. What are the nucleus? nuclear membrane? nuclear network? nuclear matrix?
7. What is the nucleolus?
8. What is the centrosome?
9. Name the properties of the cell.
10. What is meant by metabolism? growth? reproduction? irritability? motion? function?
11. How may a cell divide?
12. What is meant by direct division?
13. Name the synonyms of indirect division.
14. Describe the process of indirect cell-division.
15. What is the origin of all cells?
16. What are the primary germ-layers?
17. What tissues are developed from the epiblast? from the mesoblast? from the hypoblast?
18. What is meant by the parablast? and what tissues are developed from it?
19. Name the five groups of tissues.
20. Name the connective tissues.
21. Describe mucous tissue, white fibrous tissue, tendon, yellow elastic tissue, adipose tissue, retiform tissue, adenoid tissue.
22. Name the varieties of cartilage.
23. What is the perichondrium?
24. Describe hyaline cartilage.
25. What is its matrix? What are its lacunæ? What is its capsule?
26. Describe white fibrous cartilage.
27. Describe yellow elastic cartilage.
28. Describe cellular cartilage.

CHAPTER II.

BONE.

HISTOLOGICALLY, there are two types of bone, the *compact* and the *spongy* or *cancellated.* Covering the surface of bone, except at articular surfaces, we find a membrane, the *periosteum,* which is analogous to the perichondrium in cartilage, and, like it, consists of two layers—an *outer fibrous* and an *inner* or *cellular.* The outer layer consists principally of white fibrous tissue. The cellular layer contains many more connective-tissue cells, which gradually become more closely aggregated as we proceed toward the osseous surface, leaving no sharply defined line of demarcation between the two periosteal layers. As the bone is developed through the agency of the periosteal cells, they are sometimes called the *osteogenetic cells,* and the cellular layer, *osteogenetic layer of the periosteum.*

Compact bone occurs in the shafts of all the long bones, at the inner and outer tables of the flat bones, and as a thin layer around the periphery of the irregular bones. It is not a homogeneous structure, but is composed of thin layers of osseous substance, characteristically arranged, called *lamellæ.* At the inner and the outer (medullary and subperiostal) surfaces are a number of lamellæ of bone arranged concentrically with the periphery and called the **circumferential** or **fundamental lamellæ.** Between the inner and outer circumferential lamellæ we find the osseous substance, arranged in systems of concentric layers, each system virtually forming a tube with laminated walls. These tubes, for the most part, run parallel to the long axis of the bone, but at frequent intervals are united by diagonal branches, so that the lumens form a continuous network of canals. These canals communicate with the medullary cavity, and serve to transmit blood-vessels, nerves, and lymphatics, which are supported by a fine prolongation of the marrow reticulum. These tubes are called the **Haversian canals**; the strata of their walls, the **Haversian** or **special lamellæ**; and the canals, together with their bounding lamellæ, contents, and bone-cells (soon to be described), constitute the **Haversian system.** The more or less triangular spaces between adjacent Haversian systems are occupied

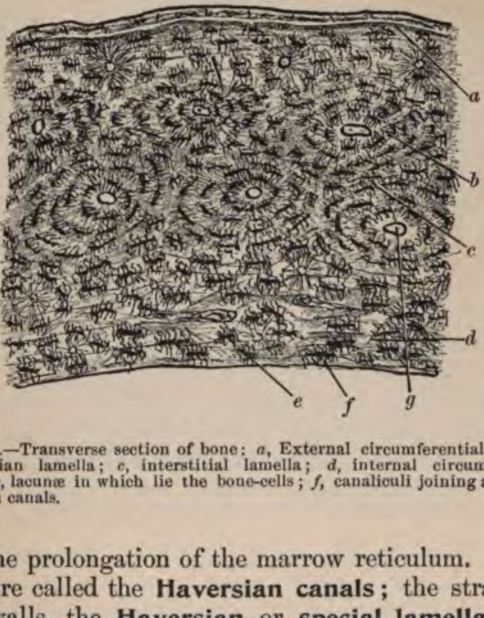

Fig. 9.—Transverse section of bone: *a*, External circumferential lamella; *b*, Haversian lamella; *c*, interstitial lamella; *d*, internal circumferential lamella; *e*, lacunæ in which lie the bone-cells; *f*, canaliculi joining above; *g*, Haversian canals.

by indefinitely arranged layers of bone, called the **interstitial** or **ground lamellæ.** Besides the Haversian canals there is another system of blood-channels. These occur scattered through the circumferential lamellæ, and have received the name of **Volkmann's canals.** Their blood-vessels communicate both with the surface of the bone and with the Haversian canals. There is no special arrangement of the bone around the Volkmann's canals, as occurs around the Haversian systems, the former being simply spaces between the lamellæ.

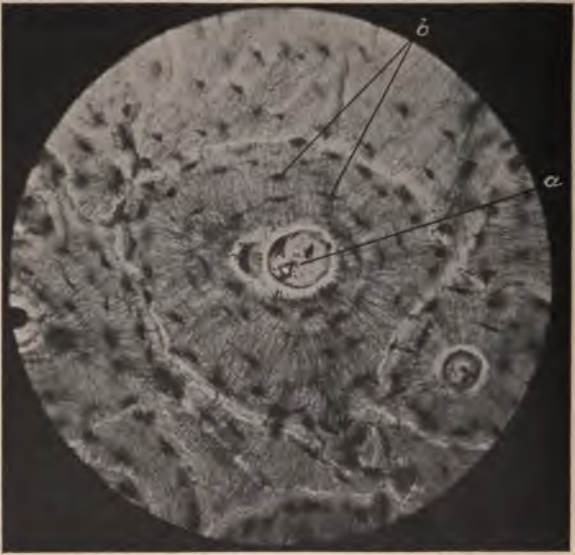

Fig. 10.—Transverse section of Haversian system: *a*, Haversian canal surrounded by lamellæ; *b*, lacunæ in transverse section, from which run numerous canaliculi.

Scattered between the individual lamellæ of all three types we find many elongated, thin spaces—the **cell-spaces,** or **lacunæ.** In the circumferential lamellæ their long axes correspond to the long axis of the bone. In the Haversian lamellæ the lacunæ are slightly curved laterally, to conform to the general concentric annular arrangement. In the interstitial lamellæ there seems to be no special arrangement, but in a general way the long axes of the lacunæ correspond to that of the bone.

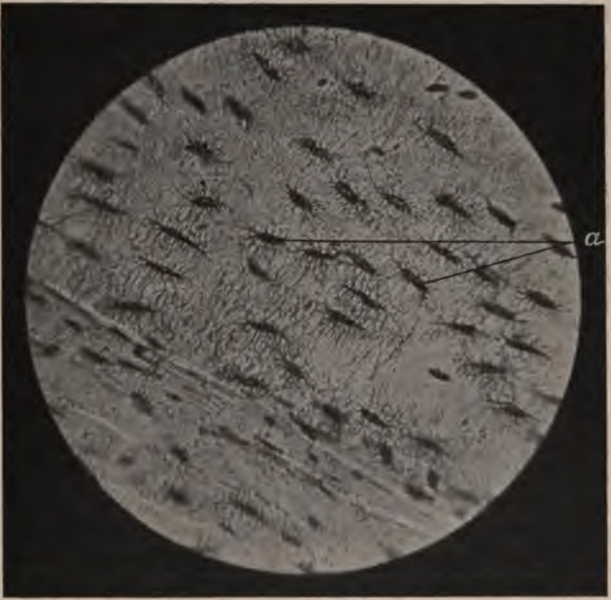

Fig. 11.—Longitudinal section of bone, showing lacunæ in longitudinal section, and numerous canaliculi: *a*, Lacunæ.

Radiating in all directions and connecting the lacunæ are minute canals, called **canaliculi,** which serve to transmit nutriment to the cells within the lacunæ and communicate with the lymphatics in the canals. While the canaliculi radiating from the lacunæ of a Haversian system intercommunicate very freely, they rarely or never have any direct connection with the adjacent systems.

In dry preparations of bone which have been *ground* to the requisite degree of thinness for microscopic examination the lacunæ and canaliculi become filled with particles of dirt and debris and appear black.

In sections which have been decalcified, however, the lacunæ are found to contain cells with long protoplasmic prolongations reaching into the canaliculi. These are the true **bone-cells**, or **bone-corpuscles.** If some of the outer lamellæ be forcibly torn off, there will be observed occasional fibers which penetrate the bone vertically to the surface. These fibers are the remains of old periosteum which in the process of bone formation have failed to be displaced by the newly deposited subperiosteal bone. They are called **perforating fibers of Sharpey.**

Spongy or **cancellated bone** differs from the compact in that the plates or spicules of which it is composed have no regular arrangement into a system, but unite irregularly to form a honeycombed mass, the cavities of which are filled with marrow. The nutrition of the bone is derived from this marrow, hence there is no need for special blood-vessels. Spongy bone is found at the ends of the shafts of long bones and at the centers of the short and flat bones (the apophyses and diploe). At this place it might be well to call attention to several points in which bone and cartilage are analogous—viz.:

1. They both have a common mesoblastic origin.
2. Both are covered by similar membranes—perichondrium, periosteum.

3. Both are composed of cells embedded in an indifferent matrix.

4. Both have similar functions—supportive framework.

MARROW.

There are two kinds of marrow: the *red*, which occurs in spongy bone,—principally in the flat bones, the vertebræ, the sternum, and the ribs,—and the *yellow*, which is found principally in the medullary cavities of the long bones of the extremities. Small prolongations also extend into the larger Haversian canals.

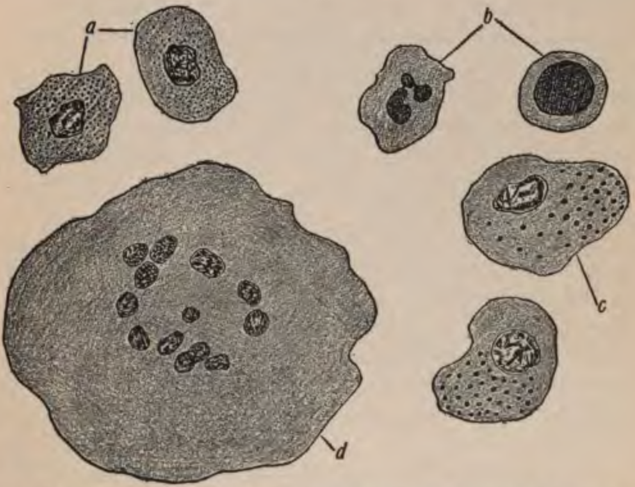

FIG. 12.—Cells from marrow: *a*, Myelocytes containing neutrophile granules; *b*, erythroblasts; *c*, eosinophiles; *d*, giant cell.

The **red marrow** contains a rather *delicate reticulum* or network of connective tissue, embedded in the interstices of which are very numerous *cells.* These cells differ widely, and may be divided into five principal classes—viz., *myelocytes, erythroblasts, eosinophiles, basophiles,* and *giant cells.*

The **myelocyte, myeloplax,** or **marrow cell,** is a moderate-sized cell capable of ameboid motion; it has a well-marked cell-body, and usually a single round nucleus. The cell-body frequently contains granules, which stain in neutral dyes (neutrophile granules). These cells are the most numerous in red marrow.

The **erythroblasts,** or **hematoblasts,** are rather smaller cells than the preceding, and contain a relatively *small cell body,* yellowish in color, containing hemoglobin (the oxygen-carrying element of the red blood-corpuscles) and a nucleus, which is frequently seen in process of division. These cells develop the colored corpuscles of the blood.

The **eosinophiles,** or **acidophiles,** resemble the myelocytes, but frequently have very irregularly shaped nuclei, and contain many large granules, which stain intensely with acid dyes (eosinophilic granules).

The **basophilic cells, plasma cells,** or **mastzellen,** resemble the eosinophiles excepting that the contained granules stain only in a basic dye. These cells occur only infrequently.

The **giant cells** are very large, irregularly shaped, ameboid cells, and usually contain many nuclei. They play an important part in the development of bone, and are then called osteoclasts. (See Developing Bone.) The nuclei of all the preceding varieties of cells are frequently seen in process of karyokinesis.

The **yellow marrow** differs from the red in that almost all the marrow-cells have been transformed into fat and the connective-tissue reticulum is slightly increased.

The marrow is well supplied with blood-vessels, lymphatics, and nerves, which come from the periosteum through the Volkmann's and the Haversian canals.

DEVELOPMENT OF BONE.

Bone may be developed in one of two ways:

1. From *cartilage*—the *intracartilaginous development.*

2. Under or between layers of *periosteum*—the *intramembranous development.*

In the embryo, all the bones of the body, with the exception of a few in the head, are outlined by solid hyaline cartilage, and covered by a membrane—the primary periosteum—having the same structure as the perichondrium in other places. The development of adult bone from these cartilages begins at certain constant and well-defined points, which are called **centers of ossification**, and are usually situated a short distance from the ends of the bones. The cartilage-cells at these points enlarge considerably and arrange themselves in longitudinal rows, the matrix meanwhile increasing somewhat in amount and becoming infiltrated with lime-salts (*primary calcification*), and thus inclosing the cells in small calcareous compartments called **primary areolæ.**

While this is going on, small blood-vessels penetrate the cartilage, and upon reaching the vertical layers of cells, proceed to absorb the transverse plates of the primary areolæ, producing numerous vertical tunnels surrounded by walls of calcified matrix. These vessels are accompanied by numerous cells from the under layer of the periosteum, called the **osteoblasts.** During this process the cartilage-cells are probably absorbed.

The osteoblasts in the tunnels now multiply greatly, and, arranging themselves around the tunnel walls, secrete around themselves a layer of bone. Within this fresh osteoblasts arrange themselves and secrete another layer of bone. This process is repeated until usually five or six concentric layers of bone, surrounding the central blood-vessels and some cells, have been deposited. These concentric layers of bone, containing the cells which produce them, and central vessels, together with nerves and lymphatics, which develop a little later, constitute the *Haversian systems* of the adult bone. At this stage of the development the bone will

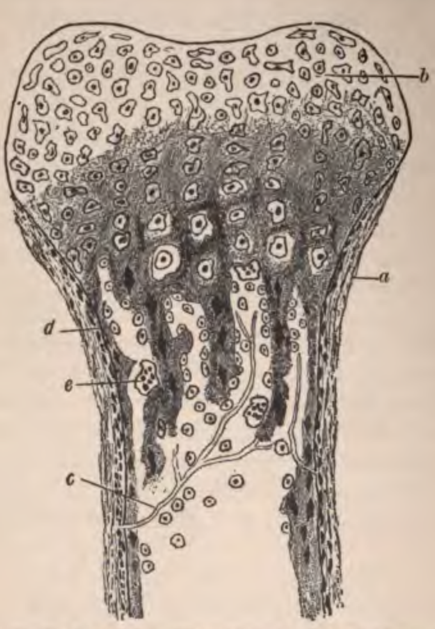

Fig. 13.—Developing bone, intracartilaginous: *a*, Periosteum; *b*, hyaline cartilage; *c*, small blood-vessel; *d*, osteoblast; *e*, osteoclast.

consist throughout its thickness of Haversian systems rather loosely held together. A number of very large, irregular, multinuclear cells (the **osteoclasts**) now appear in the more central portion of the bone and proceed to cause the disintegration of the adjacent Haversian systems, thus producing a longitudinal central canal of some size, which becomes the **medullary cavity,** and contains the elements which go to produce the marrow.

During the foregoing process the innermost cells of the periosteum multiply and secrete a layer of bone around themselves; a fresh number of cells are deposited upon this, which in turn produces a second layer. This process maintains as long as the bone continues to grow in transverse diameter, and produces thereby the adult *circumferential lamellæ.*

The medullary cavity also increases in size, but as the subperiosteal bone is deposited a little more rapidly than the central portion is absorbed, the wall of the bone increases in thickness at the same time that it is growing in circumference.

In the long bones the cartilage proceeds to calcify from the upper center of ossification downward until it meets the bone proceeding from a lower center of ossification upward to the junction of the shaft with the head of the bone. Here a band of cartilage (the **epiphyseal cartilage**) is met with, which continues to grow as fast as the process of ossification ascends. This causes the bone to grow in length while the epiphyseal cartilage maintains a constant thickness. When the bone has attained its maximum length, the cartilage finally becomes calcified also, and all subsequent increase in length is prevented.

In the cancellated bones the honeycombed structure is produced in a manner similar to the tunneling out of the medullary canal, but the process is not so complete and the osteoclasts burrow in various directions.

The intramembranous method of development differs from the preceding in that the position of the adult bone is not mapped out by the cartilage, but by a double layer of periosteum with cellular layers approximated. Between these layers branching spicules of a calcareous nature are formed, which are subsequently covered by osteogenetic cells from the periosteum. These cells proceed to secrete layers of bone about themselves, in much the same way that occurs around the Haversian canals. As bone formation advances, blood-vessels make their way into the tissue, and are accompanied by osteoclasts, which proceed to tunnel out marrow spaces, as in the heads of the long bones. The inner and outer tables of dense bone are deposited by the subperiosteal mode, as are the circumferential lamellæ in the long bones. The bones of the cranial vertex, the small bones of the face, and the inferior maxilla are the results of the intramembranous development.

Dentin is a calcareous tissue constituting the largest part of the teeth. It has many points of similarity with bone, which will be considered at length when describing the teeth.

QUESTIONS FOR CHAPTER II.

29. Name the two types of bone.
30. What is the periosteum? Give its structure.
31. Describe the general arrangement of compact bone.
32. What are the circumferential lamellæ?
33. What are the Haversian lamellæ?
34. What are the Haversian canals? the interstitial lamellæ? Volkmann's canals?
35. What are the lacunæ?
36. What are the canaliculi?
37. Describe the appearance of a dried section of bone.
38. What are the perforating fibers of Sharpey?
39. How does spongy bone differ from compact?
40. Name the points of similarity between bone and cartilage.

41. Name the two varieties of marrow.

42. Name the types of cells found in red marrow.

43. Describe the myelocyte, the hematoblasts, the eosinophiles, the basophilic cells, the giant cells.

44. Describe the yellow marrow.

45. Name the two methods of bone development.

46. What are centers of ossification?

47. What are osteoblasts? osteoclasts?

48. Describe the process of intracartilaginous bone development.

49. Describe the intramembranous method of bone development.

CHAPTER III.

MUSCLES.

THE muscular tissues form a group of specialized cells possessing contractility in a marked degree. They are all (with the exception of the small muscles of the sweat-glands) of mesoblastic origin. Three distinct types of muscle are recognized—*voluntary*, *smooth*, and *heart muscle*.

Voluntary, striated, or **skeletal muscle** is the most abundant of the three types. It forms all the skeletal muscles, and is under control of the will.

When examined microscopically, it is seen to be composed of parallel cylindric fibers, which are about $\frac{1}{500}$ of an inch wide, and vary from ¾ of an inch to 1½ inches in length. Each fiber is covered by a very delicate structureless membrane, corresponding to a cell-wall, called a **sarcolemma.** Under this sarcolemma and at the outer edge of the fiber are situated numerous oval nuclei, their long diameters parallel to the direction of the fibers. If looked at with a moderately high power objective (¼-inch to ⅛-inch), each fiber will exhibit *cross striations*, consisting of alternate dark and light bands. Under still higher magnification a dark line (the *membrane of Krause*) may be seen in the center of the light bands, and a lighter line (the *median line of Hensen*) in the center of the dark band is distinguished.

Fine longitudinal markings are also sometimes seen.

It is possible by treating the fiber chemically to split it, along the longitudinal markings, into fine fibrillæ, called **sarcostyles,** or transversely along the membrane of Krause into *discs,* each of which contains a dark band with half a light band above and below.

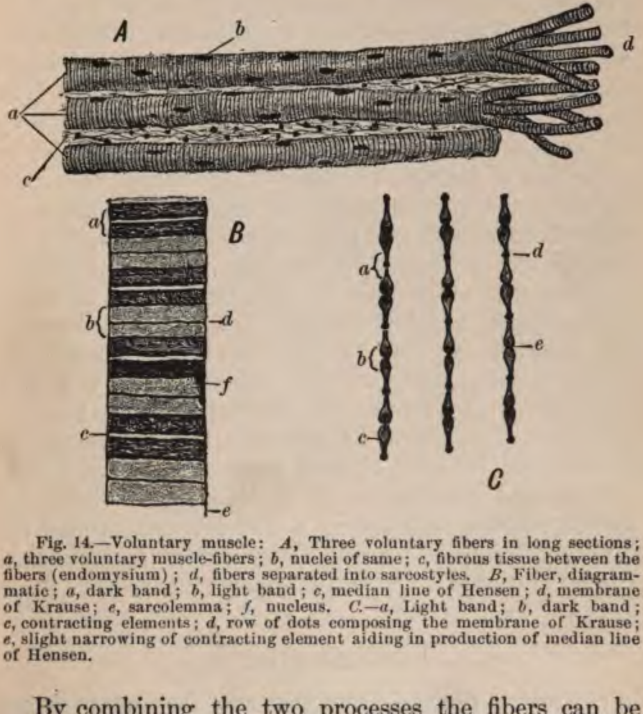

Fig. 14.—Voluntary muscle: *A*, Three voluntary fibers in long sections; *a*, three voluntary muscle-fibers; *b*, nuclei of same; *c*, fibrous tissue between the fibers (endomysium); *d*, fibers separated into sarcostyles. *B*, Fiber, diagrammatic; *a*, dark band; *b*, light band; *c*, median line of Hensen; *d*, membrane of Krause; *e*, sarcolemma; *f*, nucleus. *C.*—*a*, Light band; *b*, dark band; *c*, contracting elements; *d*, row of dots composing the membrane of Krause; *e*, slight narrowing of contracting element aiding in production of median line of Hensen.

By combining the two processes the fibers can be resolved into numerous small prisms, known as **sarcous elements.** This division, however, is entirely artificial. In reality, the sarcostyles are composed of dark, granular, fusiform, contracting elements, with enlargements at each extremity, placed end to end. The spaces between the contracting elements are filled by a clear substance, called **sarcoplasm.** As the sarcostyles run parallel, with their composing elements opposite each other, the appearance of the contiguous thick centers will be that of the dark band. The thin ends, surrounded by clear sarcoplasm, will show as the light band. The enlargements at the thin ends will produce a row of granules, which are so closely placed as to appear as a line—the membrane of Krause. The median line of Hensen is produced by a slight thinning of the contracting elements just at their centers, and by refraction of light. The individual fibers of voluntary muscle are bound together by very delicate fibers of white fibrous tissues, called the **endomysium,** to form bundles (the fasciculi). These *fasciculi* are surrounded and bound to other fasciculi by a larger band of white fibrous tissue, called the **perimysium,** and these bundles are grouped together to form the large muscles as found in dissection, and are surrounded by a still larger mass of fibrous tissue (the **epimysium**), which constitutes the sheath of the muscle. These connective tissues serve also to support numerous nerves, blood-vessels, and lymphatics. The blood-vessels break up into capillaries, which form a fine network around the individual muscle-fibers. The nerves terminate in special end-organs under the sarcolemma.

SMOOTH MUSCLE.

Smooth, plain, involuntary, or **nonstriated muscle** is found chiefly in the gastro-intestinal tract, the arteries around the various ducts, in the genito-urinary tract, and in the skin and capsules of organs. It contracts slowly and is not subject to the will. Smooth muscle is composed of spindle-shaped cells, covered by a fine sheath, which, while varying considerably in size in various locations, may be said to average about $\frac{1}{250}$ of an inch in length and $\frac{1}{5000}$ of an inch in width. In the center of each fiber is an elongated, rod-shaped nucleus. Very fine longitudinal striations may be seen in especially favorable sections. The fibers are held together by cement substance and by interlacing of their ends. Occasionally, extremely fine spiculæ branch at right angles to the fibers and aid in uniting them.

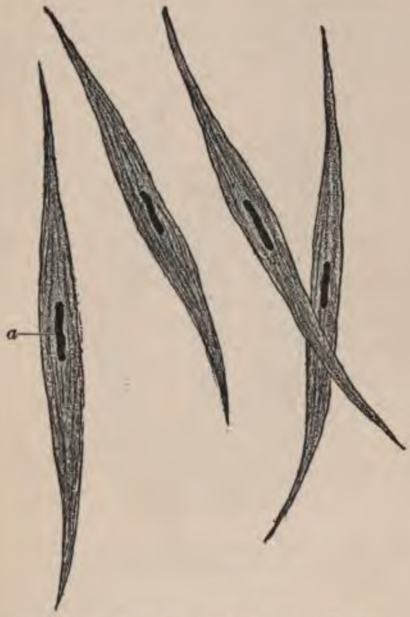

Fig. 15.—Smooth muscle-fibers: *a*, Nucleus.

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HEART MUSCLE.

Heart or **cardiac muscle,** as its name implies, is found only in the heart. It is composed of *rectangular, branching cells,* placed end to end, and joined by a small amount of clear cement substance. The fibers are more delicately cross-striated than the voluntary muscle, and, like the latter, possess fine longitudinal markings.

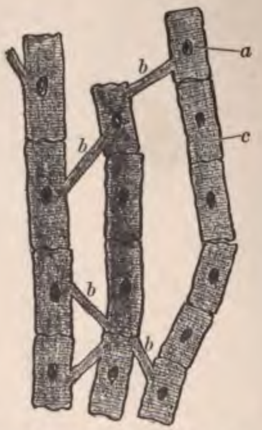

Fig. 16.—Heart muscle, semidiagrammatic: *a*, Nucleus; *b*, branch of fibers; *c*, cross-striation.

A single oval nucleus is present in the center of each cell. Small amounts of fibrous tissue and capillaries are found between the cells.

The following tabulated comparison of the three types of muscle may be of value in distinguishing them:

VOLUNTARY.	SMOOTH.
1. Fibers long, $\frac{3}{4}$ of an inch to $1\frac{1}{2}$ inches.	1. Fibers shorter, $\frac{1}{250}$ of an inch.
2. Fibers cylindric.	2. Fibers fusiform.
3. Fibers striated.	3. Fibers unstriated.
4. Fibers contain many nuclei.	4. Fibers contain one nucleus.
5. Fibers contain nuclei at edge.	5. Fibers contain nucleus at center.
6. Nuclei are oval.	6. Nuclei are elongated and rod-shaped.
7. Fibers are united by fibrous tissue, called endomysium, perimysium, and epimysium, according to location.	7. Fibers are united by cement substance, interlacing of ends, and intercellular spiculæ.

VOLUNTARY.	HEART.
1. Fibers very long.	1. Fibers shorter.
2. Fibers cylindric.	2. Fibers rectangular.
3. Fibers plainly striated.	3. Fibers more lightly striated.
4. Fibers covered by sarcolemma.	4. Fibers have no sarcolemma.
5. Fibers contain many nuclei.	5. Fibers contain single nuclei.
6. Fibers contain nuclei at edges.	6. Fibers contain nuclei in center.
7. Fibers united by fibrous tissue.	7. Fibers united by cement substance and branching.

HEART.	SMOOTH.
1. Fibers are rectangular.	1. Fibers are fusiform.
2. Fibers are cross-striated.	2. Fibers are unstriated.
3. Fibers are united by branching and by cement substance.	3. Fibers are united by cement substance, by interlacing of ends, and by intercellular spiculæ.

QUESTIONS FOR CHAPTER III.

50. Name the varieties of muscle.

51. Give the size of the voluntary muscle-fiber.

52. What is the sarcolemma?

53. What is the membrane of Krause?

54. What is the median line of Hensen?

55. What is the sarcous element?

56. Describe the structure of a voluntary muscle-fiber.

57. What kind of tissue binds together the voluntary muscle-fibers?

58. What is this fibrous tissue called in various locations?
59. Describe the blood supply of voluntary muscle.
60. How and where do the nerves terminate?
61. Describe the nuclei of voluntary muscle.
62. What is the shape and size of smooth muscle-fibers?
63. Where is smooth muscle found?
64. Describe the structure of smooth muscle.
65. How are the smooth muscle-fibers held together?
66. What is the shape of cardiac muscle?
67. Describe its structure.
68. How are the fibers held together?
69. What are the differences between voluntary and smooth muscle? voluntary and heart? heart and smooth?

CHAPTER IV.

EPITHELIUM.

EPITHELIAL tissue is essentially a cellular tissue, the intercellular substance of which is of a cement nature. The cells vary greatly as to size, shape, arrangement, and function, but in a general way may be said to be rich in cell-body (*cytoplasm*), which is usually granular, and possess a clear, vesicular, smoothly outlined nucleus, containing nucleoli. With the exception of some of the cells of the genito-urinary tract (sexual glands and ducts, kidney, and ureters), all epithelium is either of epiblastic or hypoblastic origin.

For sake of convenience we may classify epithelium in three ways—according to *shape of cells*, *arrangement of cells*, and *function of cells*:

1. Shape of cells:
   - Squamous
     - Thin scales, ovoid.
     - Polygonal, stellate.
   - Columnar
     - Cylindric, prismatic.
     - Cuboid, pyriform.
     - Fusiform, goblet-shaped, ciliated.
2. Arrangement of cells:
   - Pavement.
   - Transitional.
   - Stratified.
3. Function of cells:
   - Protective.
   - Propulsive.
   - Conductive.
   - Secretory.
   - Absorptive.
   - Nervous or neuro-epithelium.

1. **Squamous cells** are thin and flattened; they may

be found in the outer layers of stratified and transitional epithelium, as in the skin, cornea, vagina, and mucous membranes of the buccal cavities, or in a single layer (pavement) chiefly lining the alveoli of the lungs, on the posterior surface of the cornea, and on the anterior surface of the iris. The cells often vary somewhat in thickness and peripheral outline, and have been variously described as roundish. ovoid, polygonal,

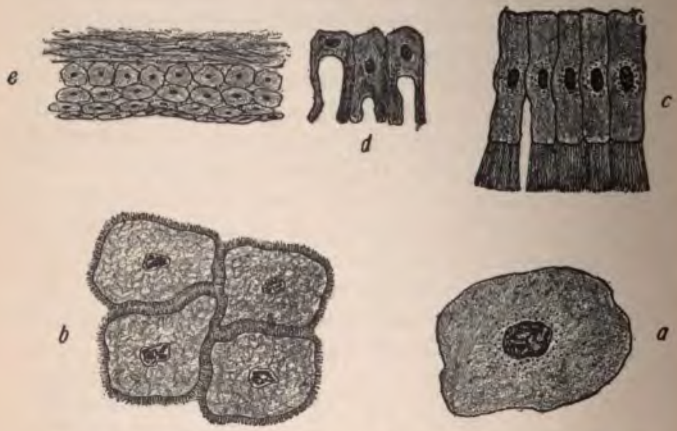

Fig. 17.—Epithelial cells from various localities: *a*, Squamous cell; *b*, prickle cell from skin; *c*, columnar ciliated cells; *d*, goblet cells; *e*, stratified epithelium.

and stellate. The stellate forms have numbers of very irregular prolongations, frequently branching. These cells frequently contain granules of pigment.

Columnar cells are longer than they are broad, and are placed with their long diameters vertical to the surface. According to their cross-section, they will be *cylindric*, *prismatic*, or *cuboid*. As their vertical sections vary, they may appear *pyriform*, *fusiform*, *goblet-shaped*, or *ciliated*.

Columnar cells may occur in a *single layer*, as lining ducts, glands, and in the intestine; or they may be *stratified*, as in the trachea. In some localities the free ends of the cells are covered by numbers of very delicate hair-like processes, called **cilia.** These cilia wave rapidly to and fro in a definite direction, with a whip-like motion, and serve to produce currents in fluids or to transport foreign particles. Ciliated cells are found

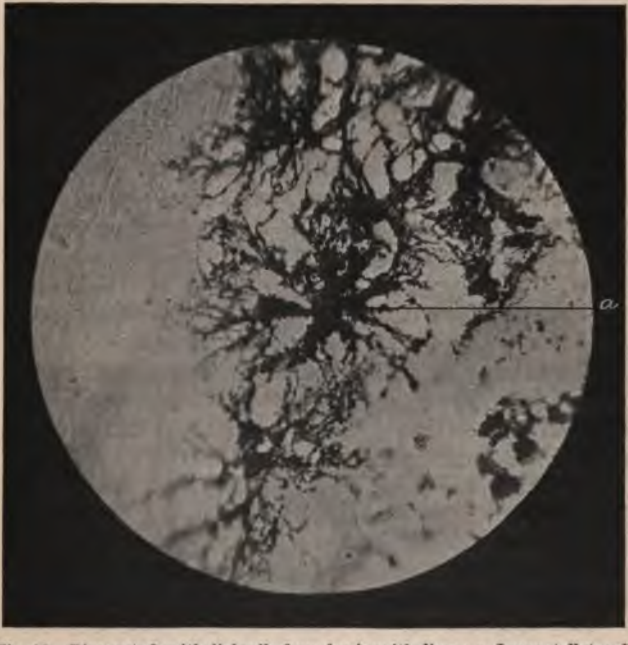

Fig. 18.—Pigmented epithelial cells from frog's epithelium: *a*, Large stellate cell the protoplasm of which is well filled with pigment.

in the nasal fossæ, trachea, bronchi, and Fallopian tubes, and in the central canal of the spinal cord.

2. According to the uses to which epithelium is adapted, the cells may vary in arrangement.

In the intestine, lung alveoli, posterior surface of cornea, lining ducts of glands, kidney, urethra, Fallopian tubes, and central spinal canal, the cells occur in a single layer resting on underlying layers of specialized fibrous tissue, called the **basement membrane.** To this arrangement the name of **pavement epithelium** may be given.

Again, in other localities, as the skin, the mucous membrane of the mouth and vagina, the cornea, and the trachea, they are arranged in many superposed layers, and are called **stratified epithelium.**

In a few places, as the pelvis of the kidney, the ureters, and the urinary bladder, an arrangement of cells only a few layers in thickness is found; the outer layers of cells are not flattened to any extent, but are more cuboid or ovoid, while virtually but a variation of the stratified variety; this arrangement has received the special name of **transitional epithelium.**

3. Epithelium may be further classified according to its *function.* The **protective** type would include such localities as the skin and the mucous membrane of the esophagus, in which the main function is to protect the underlying structures.

The **conductive** is found lining ducts the chief function of which is to transmit or to retain secretions.

Ciliated epithelium, as in the bronchi and Fallopian tubes, which causes currents in fluids and carries small particles of matter, may be termed **propulsive.**

Cells such as occur in glands and in the gastro-intestinal tract, the main function of which is either to secrete or to absorb, may be called **secretory** and **absorptive** respectively.

In the organs of special sense—skin, tongue, nose, eye, and ear—certain types of epithelium are found which are very intimately connected with the nervous system. These cells possess some of the characteristics of both nerve and epithelium, and have received the compound name of **neuro-epithelium.**

Besides the foregoing classes, there are some *specialized substances,* as the *hair, nails,* and *enamel of the teeth,* which are epithelial derivatives, and will be considered under their appropriate heads.

QUESTIONS FOR CHAPTER IV.

70. Describe the general characteristics of epithelium.

71. From what germ layers is it developed?

72. How may it be classified?

73. Give a classification with regard to the shape of the cell, the arrangement of cells, and the function of the cells.

74. Describe and give location in which squamous cells are found; columnar cells.

75. What is pavement epithelium, and where is it found? stratified epithelium? transitional epithelium?

76. What is meant by protective type, conductive type, ciliated, propulsive, secretory, and absorptive?

77. What is meant by neuro-epithelium?

78. Name the specialized epithelial structures.

CHAPTER V.

NERVES.

Nerves are long, highly specialized fibers originating in *nerve-cells*, carrying impulses, and usually terminating in *special end-organs*.

The combination of one nerve-fiber with its cell and terminals is called a **neuron.**

It may probably safely be said that all true nerve tissue is developed from the epiblast or ectoderm.

A **nerve-cell** is one of the largest cells in the body. It contains a large **spheroid nucleus**, rather poor in chromatin, hence staining not very deeply, and usually one or more well-marked **nucleoli.**

The cell-body, or cytoplasm, contains a greater or less number of granules, which stain in a characteristic manner, and are named **chromophilic granules.**

The nerve-cells vary greatly in shape, occurring as unipolar (one pole or projection), bipolar, tripolar, and multipolar.

One of the poles in the nerve-cell, called the **axis-cylinder process**, is enormously extended, and becomes the axis-cylinder of the nerve-fiber.

The other processes of the cell may divide and subdivide until a dense feltwork of interlacing fibers is formed about the cell. These processes are called **dendrites.**

Nerves are principally of two types—those consisting of the *medullated* or *white*, and those consisting of the *nonmedullated* or *gray fibers.*

The **medullated fiber** consists of a very delicate

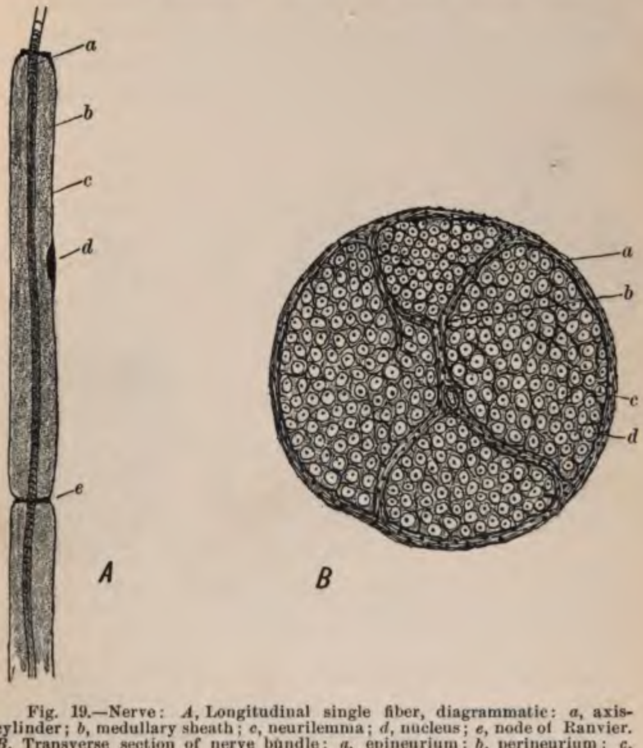

Fig. 19.—Nerve: *A*, Longitudinal single fiber, diagrammatic: *a*, axis-cylinder; *b*, medullary sheath; *c*, neurilemma; *d*, nucleus; *e*, node of Ranvier. *B*, Transverse section of nerve bundle: *a*, epineurium; *b*, perineurium; *c*, endoneurium; *d*, transverse section of medullated nerve-fiber.

thread, the **axis-cylinder,** which is continuous throughout the length of the nerve, and is in reality a prolongation of the nerve-cell. The axis-cylinder is the portion of the nerve which transmits impulses. Enveloping the axis-cylinder is a fatty material (myelin), called the **medullary sheath**, or the **white substance of Schwann.** This medullary sheath begins a short distance from the nerve-cell and continues until close to the termination of the fiber.

Surrounding the medullary sheath of the peripheral medullated nerve-fibers is a delicate sheath, called the **neurilemma.** In the *central nervous system* medullated fibers occur which *have no neurilemma.* About every $\frac{1}{25}$ of an inch in the course of the nerve-fiber the neurilemma dips down to the axis-cylinder, thus forming periodic constrictions—the so-called **nodes of Ranvier.**

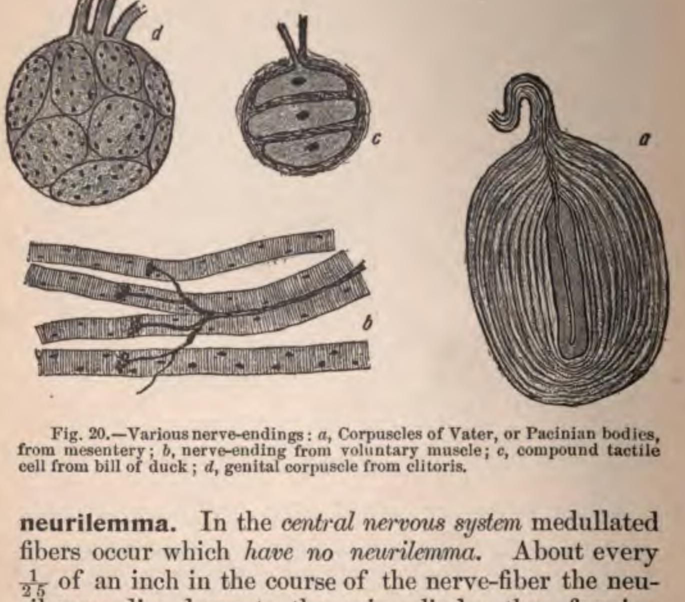

Fig. 20.—Various nerve-endings: *a*, Corpuscles of Vater, or Pacinian bodies, from mesentery; *b*, nerve-ending from voluntary muscle; *c*, compound tactile cell from bill of duck; *d*, genital corpuscle from clitoris.

At the under surface of the neurilemma are found the **nuclei**, one of which is placed in the center of each internodal segment. Special methods of staining disclose small oblique markings in the white substance of Schwann (the *clefts of Lantermann*), the exact significance of which has not been determined.

In the peripheral nerves the individual fibers are held together by fine fibrillæ of fibrous tissue, called the **endoneurium,** and grouped into bundles (*fasciculi*), which are surrounded by a denser band of the fibrous tissue, which is in connection with that between the fibers.

This tissue surrounding the fasciculi is named the **perineurium.** Numbers of fasciculi are grouped together to form the nerve-trunks, as met with in dissection, and are bound together by a thick layer of fibrous tissue, called the nerve-sheath, or **epineurium.**

In the central nervous system the nerve-fibers are held together by a specialized type of tissue, called **neuroglia.** This neuroglia tissue is composed of irregular cells (*neuroglia cells*) with very many fine, radiating processes, which interlace with the processes of adjoining cells to form a dense feltwork.

NONMEDULLATED NERVE-FIBERS.

The *nonmedullated, gray, pale,* or *Remak's fibers* differ from the medullated principally in that they have no medullary sheath, their nuclei are more numerous, and the fibers frequently inosculate and have occasional fusiform dilatations.

These fibers occur principally in the sympathetic system, although occasional pale fibers are found associated with medullated nerves.

GANGLIA.

Fusiform enlargement occasionally occurs in the course of some of the nerve-trunks, more especially in the sympathetic nerve and in the sensory nodes of the spinal nerves.

These enlargements are composed of nerve-fibers, connecting with large and rather spheric nerve-cells, and are called the **ganglia.**

The *ganglion cells* are distributed mostly in more or less longitudinal rows, and usually have two nerve-fibers (an efferent and an afferent) connected at one pole. Some of the cells, however, are bipolar.

When a medullated fiber joins a ganglion cell the medullary sheath disappears a short distance from the cell. In all nerves, however, the neurilemma continues, and forms a *nucleated sheath* for the ganglion cell.

NERVE-ENDINGS.

Nerves terminate in one of two ways:

1. By dividing into fine arborizations, called **terminal plexuses.**
2. By ending in special structures, called **end-organs.**

The first type of termination is found in many of the sensory nerves of the skin, mucous membrane, and cornea. The ends of the fibers may lie between the epithelial cells, or may ramify in the basement membrane.

Of the end-organs many types are known, occurring in the lower animals as well as in man.

Some of the sensory fibers terminate in crescentic cells, called **tactile cells.**

In many localities fibers terminate in complex arrangements of tactile cells, which are then called **compound tactile cells.** Some of the most important of these are:

Corpuscles of Meissner, or *tactile corpuscles of the skin*, which occur in the papillæ of the corium. These consist of a vertically elongated mass of compressed tactile cells, the upper portion of which is just below the epithelium and the lower portion of which gives entrance to the nerve-fibers.

The *Pacinian corpuscles*, or *corpuscles of Vater*, occur in many localities, as in the palms of the hands, the soles of the feet, the mesentery, and the genital organs. They are the largest of the terminal organs, sometimes reaching a size of $\frac{1}{20}$ of an inch (1.25 mm.). They are oval in shape, and consist of a series of concentric layers of fibrous tissue and hyaline elastic substance, inclosing a small clear space in the center, filled with a transparent, jelly-like material. The medullated fiber enters at one pole and loses its sheath, the axis-cylinder proceeding as a wavy line in the central space.

The *end-bulbs of Krause* are found in the conjunctiva. They consist of a nucleated capsule, in which the axis-cylinder of the nerve-fiber is convoluted. They are much smaller than the preceding.

The *genital corpuscles* of the clitoris and penis may be considered as a compound end-bulb, several end-bulbs, each connecting with a separate nerve-fiber, being partly fused together.

Nerve-endings in Smooth Muscles.

The nerves supplying the smooth muscles are of the nonmedullated variety, and are principally derived from the sympathetic system. The nerve-fibers break up into plexuses of axis-cylinders, which lie in the intercellular spaces. From these, fine processes enter the muscle-cells and terminate in or upon the nucleus.

Nerve-endings in Voluntary Muscle.

Both *sensory* and *motor nerves* are found in voluntary muscle. The *sensory fibers* form a network between the muscle-fibers, while the motor fibers enter them. When the *motor fibers* enter a muscle-fiber, they lose their medullary sheath, and the neurilemma blends with the sarcolemma of the muscle.

The axis-cylinder now spreads out into a tortuous, irregularly bulbous, branching mass, embedded in a soft, nucleated, protoplasmic substance. This is called the **sole plate**, and lies upon the muscle substance just under the sarcolemma.

Every muscle-fiber has one of these nerve-endings, and sometimes several.

Nerve-endings in Tendons.

Tendons have several types of nerve terminations :

1. Some medullated fibers, after running a short distance in the tendon, terminate in a dilatation closely resembling the end-bulbs of Krause.

2. The *tendon spindles* consist of a dilated fusiform bundle of tendon fibers, which is entered by a very small medullated nerve-trunk. This nerve divides into its ultimate fibrillæ, which ramify throughout the spindle and terminate in slightly bulbous enlargements.

QUESTIONS FOR CHAPTER V.

79. What are nerves?

80. What is a neuron?

81. From what layer of the embryo are the nerves probably developed?

82. Describe the nerve-cell. What are dendrites?

83. Name the two principal types of nerves.

84. What is the axis-cylinder? medullary sheath? neurilemma?

85. Is the neurilemma ever absent in medullated fibers? and if so, where?

86. What are the nodes of Ranvier? the clefts of Lantermann?

87. Describe a medullated nerve-fiber.

88. Where are the nuclei situated?

89. How are the nerve-fibers held together, and what are the supporting tissues called?

90. Describe a nonmedullated nerve-fiber, and tell where they occur.

91. Describe a ganglion.

92. Name two methods of nerve termination.

93. What are tactile cells? tactile corpuscles? Pacinian corpuscles? end-bulbs of Krause?

94. Genital corpuscles?

95. Describe the nerve-endings in smooth muscle, voluntary muscle, and tendon.

CHAPTER VI.

THE VASCULAR SYSTEM.

The blood-vessels compose a system of closed tubes, of *mesoblastic origin*, which are divided structurally into arteries, veins, and capillaries.

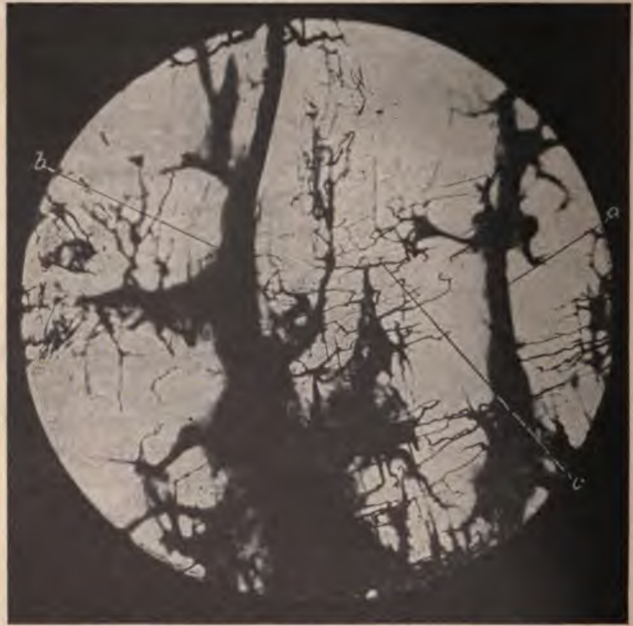

Fig. 21.—Capillary network connecting small arteriole and vein: *a*, Small arteriole; *b*, vein; *c*, capillaries.

ARTERIES.

An *artery* has three coats, called respectively *outer*, *middle*, and *inner*. The **inner coat, serous coat,** or **tunica intima,** consists of a single layer of thin, flat, elongated *endothelial* cells, united by a delicate cement substance, which rests upon a *subendothelial layer* of fibrous tissue. Surrounding this layer of fibrous tissue is a wavy band of *yellow elastic tissue.* In the larger arteries this elastic tissue forms a thick sheet, in which more or less irregular openings occur. It is then called the **fenestrated membrane of Henle.**

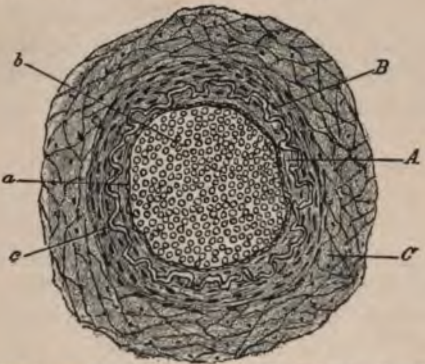

Fig. 22.—Blood-vessel: *A*, Tunica intima; *B*, tunica media; *C*, tunica adventitia; *a*, endothelial lining; *b*, blood-corpuscles; *c*, fenestrated membrane of Henle.

The **middle coat, muscular coat,** or **tunica media,** surrounds this fenestrated membrane of Henle, and consists principally of smooth muscle, most of which runs circularly around the artery. Some few fibers of fibrous and yellow elastic tissue are also found interspersed among the muscle-cells, especially in the larger arteries.

The **outer coat, fibrous coat,** or **tunica adventitia,** consists of fibrous tissue in rather dense bundles, with occasional fibers of yellow elastic tissue.

The inner coat presents a smooth surface, which offers scarcely any resistance to the blood current.

The muscular coat is under control of the vasomotor nerve system, and, by contracting or dilating, changes the size of the lumen, thereby regulating the amount of blood passing through a given vessel.

The outer coat gives strength to the artery, and serves to sustain it in its relations to the adjacent tissues.

VEINS.

The **veins** differ from the arteries only in the relatively small size of their muscular coat and the large amount of fibrous coat. Their walls are thinner in proportion to the lumen, and when cut they tend to collapse.

CAPILLARIES.

The larger arteries branch repeatedly until the finest arterioles are reached, when they lose their outer two coats and continue as thin tubes consisting of only a single layer of endothelial cells, the continuation of the endothelial lining of the larger vessels. Occasionally, the endothelial cells do not fit together exactly, and small spaces occur, which are filled with cement substance. These are called **stigmata**, and are probably the first places through which the white blood-corpuscles pass in inflammations.

The larger vessels are *supplied with nutrition* by smaller vessels, which ramify within their coats. These have received the name of **vasa vasorum.**

Lymphatics also occur in the outer coat of the larger vessels, and some of the smaller blood-vessels are completely surrounded by narrow lymphatic spaces—the **perivascular lymphatics.**

THE HEART.

The heart is lined by the **endocardium,** which is similar in structure and continuous with the tunica intima of the blood-vessels.

Under this is the **myocardium,** or heart muscle, which has already been considered.

The outer surface of the heart is covered by the **pericardium,** a serous membrane containing a membrane of fibrous tissue, on the free surface of which are flat, irregular endothelial cells.

The **valves** of the heart are broad, flat *reduplications of the endocardium,* between the two layers of which is a plate of very tough, dense fibrous tissue.

The heart contains many *lymphatics,* some of which run between the muscle-fibers; others are found around the coronary arteries.

Both *medullated* and *nonmedullated nerve-fibers* occur in abundance, the former being chiefly branches of the pneumogastric; the latter, from the sympathetic system.

Numerous *ganglia* are also found in the course of the nerves.

THE BLOOD.

The blood may be considered as a mesoblastic tissue consisting of cells with a fluid intercellular substance.

The cellular elements of the blood are called **corpuscles;** the fluid portion, the **plasma,** or **liquor sanguinis.**

The principal corpuscles are the *colored,* the *colorless,* and the *blood platelets.* Other forms that occur are the *dust corpuscles*, the *shadow corpuscles*, the *microcytes*, and the *spheric red corpuscles*. **The colored corpuscles, red corpuscles,** or **erythrocytes,** are round, biconcave discs. When viewed singly under the microscope, they have a yellowish-green color, the characteristic red color of blood being produced only by the superposition of great numbers of cells. Their number varies somewhat in different individuals, and is slightly greater in the male than in the female. A cubic millimeter ($\frac{1}{25}$ of an inch) of blood in the male will contain, on an average, 5,000,000 colored blood-cells, whereas the female will average about 4,500,000.

In man the red cells are singularly regular in size, measuring $\frac{1}{3200}$ of an inch (7.5 microns) in breadth and about $\frac{1}{12000}$ of an inch (2.08 microns) in thickness at the edge. The thickness of the center depends upon the amount of concavity, and varies much in different cells. In stained preparations the center appears clear, and is called the "**delle.**"

Structurally, the colored cells are surrounded by a clear, extremely delicate *limiting membrane* (virtually a cell-wall), inclosing the body of the cell, the **hemoglobin,** which is the oxygen-carrying element. In the adult no nuclei are found in the colored cells, although in the embryo and a few days after birth some nucleated red cells occur. When allowed to remain quietly outside the blood-vessels, they tend to arrange themselves into *stacks*, or *rouleaux*, resembling rolls of coin.

Action of Reagents.

Upon the addition of *water* to the blood the red cells swell up until they become spheric in outline, and lose their hemoglobin, which is dissolved out.

When acted upon by *dilute saline solutions*, minute spines develop around the surface of the cell, giving it somewhat the appearance of a horse chestnut bur. Corpuscles in this condition are said to be **crenated.** If the strength of the solution be increased, the cells will eventually shrivel up into an unrecognizable mass.

Almost all *acids,* especially *acetic acid,* decolorize the cells and cause them to become spheroid in outline.

Tannic acid in a 1 % solution causes the hemoglobin to escape from the cell and to coagulate in minute beads at the edge of the limiting membrane. If the solution used is too strong, the hemoglobin will be coagulated within the cell.

Colored Corpuscles in Other Animals.

The red blood-cells of all mammals (with the exception of the camel tribe) differ only in size. In the camel tribe the red cells are biconcave, *oval,* and have *no nuclei.* In birds and cold-blooded animals they are *oval,* biconvex and have *well-marked* usually elongated *nuclei.*

The following is a table showing the size of the colored cells in various animals:

Proteus,	$\frac{1}{400}$	of an inch	(62.5 microns).
Newt,	$\frac{1}{814}$	" "	(30.7 ").
Toad,	$\frac{1}{1043}$	" "	(23.9 ").
Shark,	$\frac{1}{1142}$	" "	(21.6 ").
Snake,	$\frac{1}{1274}$	" "	(19.6 ").
Lizard,	$\frac{1}{1555}$	" "	(16.7 ").
Crocodile,	$\frac{1}{1231}$	" "	(20.3 ").
Ostrich,	$\frac{1}{1649}$	" "	(15.1 ").
Electric eel,	$\frac{1}{1745}$	" "	(14.4 ").
Pike,	$\frac{1}{2000}$	" "	(12.5 ").
Pheasant,	$\frac{1}{2128}$	" "	(11.7 ").
Perch,	$\frac{1}{2464}$	" "	(10.15 ").
Pigeon,	$\frac{1}{2317}$	" "	(9.56 ").
Humming-bird,	$\frac{1}{2666}$	" "	(9.375 ").
Elephant,	$\frac{1}{2745}$	" "	(9.2 ").
Sloth,	$\frac{1}{2907}$	" "	(8.6 ").
Whale,	$\frac{1}{3125}$	" "	(8.0 ").
Camel,	$\frac{1}{3123}$	" "	(7.6 ").

Man,	$\frac{1}{3200}$	of an inch	(7.5 microns).
Monkey,	$\frac{1}{3378}$	" "	(7.4 ").
Dog,	$\frac{1}{3500}$	" "	(7.1 ").
Guinea-pig,	$\frac{1}{3500}$	" "	(7.1 ").
Bear,	$\frac{1}{3511}$	" "	(7.0 ").
Rabbit,	$\frac{1}{3511}$	" "	(7.0 ").
Cat,	$\frac{1}{4000}$	" "	(6.25 ").
Pig,	$\frac{1}{4166}$	" "	(6.0 ").
Horse,	$\frac{1}{4600}$	" "	(5.9 ").
Sheep,	$\frac{1}{5000}$	" "	(5.0 ").
Ox,	$\frac{1}{5208}$	" "	(4.8 ").
Goat,	$\frac{1}{6250}$	" "	(4.0 ").
Musk deer,	$\frac{1}{12325}$	" "	(2.4 ").

Colorless Blood-corpuscles.

The **colorless corpuscles, white blood-cells,** or **leukocytes,** are briefly described as **nucleated cells,** averaging about $\frac{1}{2500}$ of an inch (10 microns) in diameter, containing no cell-wall, and often having the power of spontaneous or *ameboid motion* from place to place.

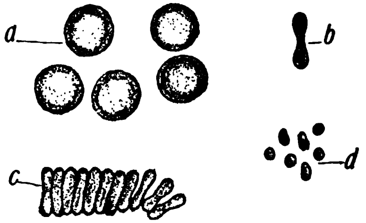

Fig. 23.—Cells of blood: *a*, Colored blood-corpuscles seen on the flat; *b*, on edge; *c*, in rouleau; *d*, blood platelets.

There are many varieties of colorless corpuscles occurring normally in the blood. The five principal types are:

Small lymphocytes.
Large lymphocytes.
Polymorphonuclear neutrophiles.
Eosinophiles.
Basophiles.

The **small lymphocytes** form about 20% of all the white cells. They are the smallest of the white cells, measuring only from $\frac{1}{5000}$ to $\frac{1}{2500}$ of an inch (5–10 microns) in diameter.

The nucleus is usually round and surrounded by a relatively small spheric cell-body of *clear* cytoplasm.

Large lymphocytes constitute about 7% of the white blood-cells. They are much larger than the last-named variety, about $\frac{1}{1600}$ of an inch (15 microns) in diameter, and resemble the small lymphocytes, with the exception that the cell-body is proportionately a trifle greater.

Polymorphonuclear neutrophiles are the most numerous types of white blood-cells, forming about 70% of the total number. They are about the size of the large lymphocytes. The nucleus is very irregularly lobated in outline, often appearing to be multiple, but usually these seemingly separate lobes are connected by delicate threads of nuclear substance. The cell-body is peculiar, in that it contains many very fine *granules* scattered through it, which will stain only in a mixture of acid and basic dyes. These cells, as well as the next two varieties, possess the power of *ameboid movement.* This ameboid motion is so called from its resemblance to the action of a unicellular animal—the ameba. The cell so moving first advances a small projection of cytoplasm, called a *pseudopod,* into which the rest of the cell slowly flows. By virtue of this power of movement the white cells frequently leave the blood-vessels and wander short distances in the surrounding tissues. The "migratory" cells of white fibrous tissue are examples of this. The irregular shape of the nuclei in the ameboid cells is probably due to the twisting and bending they are subjected to through the movement of the cells.

Those of the white blood-cells which have ameboid motion also have the peculiar property of engulfing and carrying away certain foreign particles with which they may come in contact, and cells may frequently be seen with several small particles within their cell-bodies which they have taken up. When one of these cells comes in contact with a foreign particle, it apparently adheres to the particle, and a depression forms in the cell at the point of contact. The depression deepens and the cell-body closes over the top, thus inclosing the particle. In diseased conditions cells frequently are found containing bacteria which they have engulfed; and when so found, are called **phagocytes.**

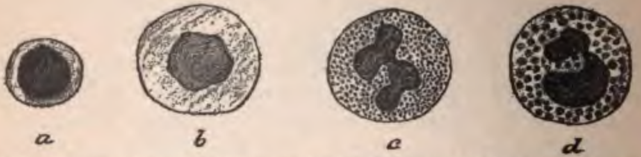

Fig. 24.—Various forms of leukocytes: *a*, Small lymphocyte; *b*, large lymphocyte; *c*, polymorphonuclear neutrophile; *d*, eosinophile.

Eosinophiles constitute only about 3% of all the white cells; they are colorless cells, and closely resemble the last-described variety, but differ chiefly in the fact that the granules contained in the cell-body are much coarser, fewer in number, and will stain only in acid dyes, such as eosin.

Basophiles, mast-cells, or **mastzellen,** are quite rare, constituting only about 0.25% of all the white cells.

They differ from the neutrophiles principally in the fact that their granules will be stained only in a basic dye.

The white blood-cells are not so numerous as the red, occurring in the ratio of 1 of the former to between

400 and 600 of the latter. This would make between 8300 and 12,500 white cells in every cubic millimeter ($\frac{1}{25}$ of an inch) of blood. The exact number varies with the condition of the individual, the time of day, and the nutrition.

Blood Platelets.

Blood platelets, blood plaques, or **third corpuscles,** are small round or oval bodies, one-fourth the size of red blood-cells, which occur in large but varying numbers in the blood. They are rather unstable structures, and require some care to see properly: The exact function of the blood platelet is at present unknown, although it is supposed by many to be related to the formation of fibrin.

The **dust corpuscles** are small granules, much smaller than any of the preceding forms, of an albuminous nature, and have been originally the granules of white blood-cells. The escape and dissemination of these granules from both eosinophiles and neutrophiles has been directly observed by Sangree and Leroy.

Shadow corpuscles are occasionally met with in normal blood. They are apparently the remains of the limiting membrane of red blood-corpuscles from which the hemoglobin has escaped.

At infrequent intervals red blood-corpuscles that are either very small (**microcytes**) or *spheric* in form may be encountered.

Crystals.

Hemoglobin easily crystallizes out from dried preparations of blood, and then appears as long rhombic prisms of a red color.

Hematin is also met with in dried blood, and occasionally in abnormal conditions, as a dark brown or black pigment.

Hematoidin occurs as yellowish crystals around areas of extravasation of blood, also in pathologic and chronic irritations. When treated with ferrocyanid of potassium and an acid they give a blue reaction.

Probably the most important blood crystal is **hemin**, or **Teichmann's crystals.** They are produced when blood, fresh or dried, is heated in the presence of acetic acid and salt. They are narrow rhombic plates, of a dark brown color, and extremely small. The presence of *hemin* crystals in a material treated as just described is a positive test for blood, but will not give any light as to what animal it came from.

Development of Blood-corpuscles.

The first *red blood-corpuscles* are derived directly from the mesoblastic cells, and are nucleated and colorless. These multiply somewhat, and eventually become smaller, lose their nuclei, and acquire hemoglobin. Later in fetal life the liver and spleen contribute certain of the colored blood-cells. After birth, however, the supply is maintained by the direct division of the erythroblasts or hematoblasts of the red bone-marrow.

The *colorless corpuscles* originate principally in the lymphoid tissues and spleen.

These lymphoid corpuscles become dislodged, and are carried along either in the lymphatic stream or, in the case of the spleen, in the blood current, and there become the small lymphocytes of the blood. The probability is that there they undergo further development into the neutrophile (the adult cell), and later into the eosinophile (sometimes called an overripe cell).

QUESTIONS FOR CHAPTER VI.

96. From what layer of the embryo is the vascular system derived?

97. Name the three coats of an artery.

98. Describe the inner coat; the middle coat; the external coat.

99. How do veins differ from arteries?

100. Give the structure of the capillaries.

101. How are blood-vessels nourished?

102. What structures compose the heart? Describe each.

103. What are the valves of the heart and veins, and describe them?

104. Of what is the blood composed?

105. Give the size and shape of the colored corpuscles.

106. Give the number occurring in normal blood, and describe the structure of the colored blood-cell.

107. What action has water upon the colored blood-cell? dilute saline solutions? acids? tannic acid?

108. Describe the colored corpuscles of birds and cold-blooded animals, and name the differences between these and warm-blooded animals.

109. Give the general characteristics of the colored corpuscles.

110. Name the varieties of colorless corpuscles and give the percentage of each occurring in normal blood.

111. Describe the small lymphocytes; large lymphocytes; polymorphonuclear neutrophiles; eosinophiles; and basophiles.

112. What is meant by phagocytosis?

113. Describe the blood plates.

114. What are dust corpuscles?

115. What are shadow corpuscles? microcytes?

116. What crystals may be obtained from blood?

117. What are Teichmann's crystals, and how are they produced?

118. From what are the red blood-cells developed? the colorless cells?

CHAPTER VII.

THE LYMPHATIC SYSTEM.

THE lymphatic system comprises the *lymph-vessels*, the *lymph*, the *lymph-nodules*, the *spleen*, the *thymus*, the *tonsils*, and the *serous membrane* of cavities.

The **lymph-vessels** form a richly branching and anastomosing system of tubules, which vary in size from 1 mm. ($\frac{1}{25}$ of an inch) to the minutest capillaries. The smaller vessels continually join to form larger ones, until the **thoracic duct** is reached, which is of considerable size and empties directly into the subclavian vein, so that the cavities of the lymphatics are continuous with those of the vascular system. In structure the lymphatics are similar to the blood-vessels, the larger ones possessing three coats, the lymph capillaries possessing only one coat of endothelial cells. Frequently throughout the course of the lymph-vessels folds of the endothelial coat occur, which may be reinforced by a layer of fibrous tissue, and constitute the **valves.**

These valves prevent the blood at the thoracic duct from being forced into the lymphatics, and at the same time compel the lymph to flow in one direction only. The smaller lymph-vessels have irregular dilatations throughout their extent, which in a measure serve a similar purpose.

The lymphatics are almost universally distributed throughout the body, possibly to a greater extent in fibrous and areolar tissue. Around the nerves and smaller blood-vessels they sometimes form an inclosing tube, in which case they are called **perineurial** and **perivascular lymphatics** respectively.

LYMPH.

The **lymph** is a clear, whitish fluid, which contains many freely floating *cells* and *fatty granules.*

The cells resemble the colorless corpuscles of the blood, the small lymphocytes, however, being very greatly in excess of the other types. The fatty granules are constantly present in varying amounts, but are very much increased during and just following digestion.

DIFFUSE ADENOID TISSUE.

In many areas throughout the body, especially in the tunica propria of mucous membranes, as in the lungs and digestive tract, masses of **adenoid tissue** occur. This adenoid tissue is formed of a network of fibrous tissue and branching connective-tissue cells (*retiform tissue*), which entangle and support large numbers of cells resembling the small lymphocytes of the blood, and called in this location *lymphoid cells.*

In some places adenoid tissue occurs in small amounts, which merge gradually into the surrounding tissue without any sharp line of demarcation.

LYMPH-FOLLICLES.

In other localities the adenoid tissue may be surrounded by an envelope of fibrous tissue, in which a few fibers of smooth muscle may be interspersed, called the **capsule.**

LYMPH-GLANDS.

Lymph-glands or **lymph-nodes** are aggregations of lymph-follicles occurring in the course of lymph-vessels. The glands are usually bean-shaped. The lymph-vessels and blood-vessels enter at the central depression, or hilum, from which point they are distributed throughout the structure.

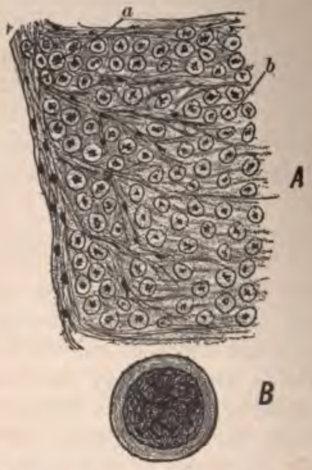

Fig. 25.—Adenoid tissue: *A*, *a*, Showing cells held together by retiform tissue; *b*, showing retiform tissue cells having been washed out. *B*, Single lymphoid cell.

The *capsule* is usually well marked, and sends prolongations into the substance of the gland, which have received the name of **trabeculæ**, and which in turn divide and subdivide until they eventually become continuous with the retiform tissue forming the framework of the gland.

An *outer* or *cortical* and an *inner* or *medullary* portion may be readily distinguished.

The cortical portion is composed of a number of dense lymph-follicles, placed side by side and separated from the capsule by a narrow cleft, the *circumferential lymph-sinus*, which, however, is frequently bridged by small branching processes of connective-tissue cells.

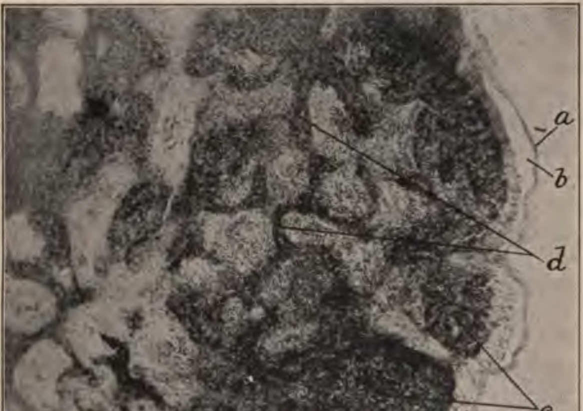

Fig. 26.—Lymph-node: *a*, Capsule; *b*, circumferential lymph-sinus; *c*, lymph-follicles; *d*, lymph-cords.

The medullary portion is more open in appearance, and combines alternate bands of adenoid tissue, the so-called **lymph-cords,** and open spaces, the **lymph-sinuses,** which serve to transmit the lymph. These sinuses are frequently traversed by fine fibers of connective tissue.

The blood-vessels, after entering at the hilum, break up into a rich capillary network, which is principally distributed to the adenoid tissue, and reunite to form the veins which leave the gland at the hilum also. Occasionally, some small blood-vessels may enter at various points on the capsule.

A few nerves may be found, both of the medullated and the nonmedullated varieties.

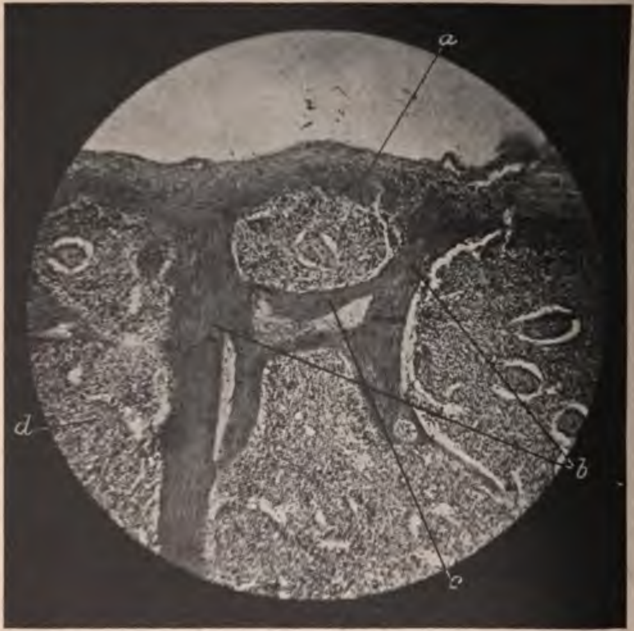

Fig. 27.—Spleen: *a*, Capsule; *b*, two trabeculæ extending perpendicularly into substance of organ; *c*, small transverse band uniting trabeculæ and containing a small blood-vessel; *d*, splenic pulp.

SPLEEN.

The **spleen** is a lymphoid organ, and differs from a lymphatic gland principally in the arrangement of its blood supply and in having no medullary portion.

It is surrounded by a dense *capsule* of fibromuscular tissue, which sends *trabeculæ* down at right angles into the substance of the organ. These trabeculæ divide repeatedly to form the framework of the splenic pulp. This framework is filled with lymphoid cells.

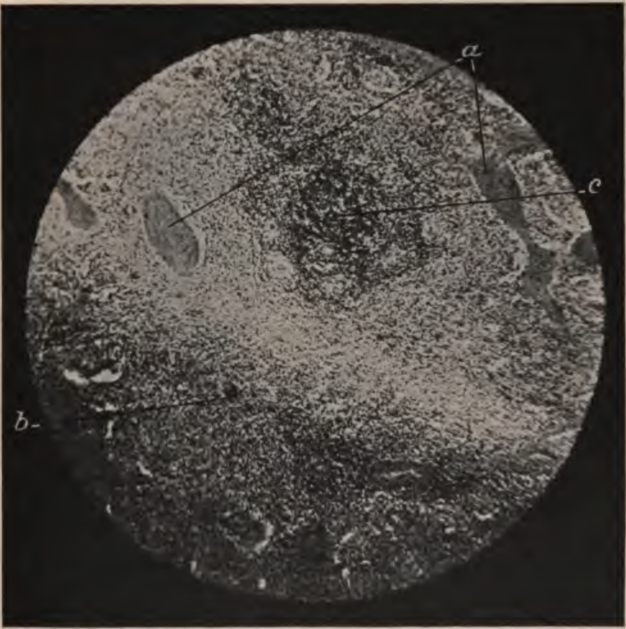

Fig. 28.—Spleen. Section taken some distance from surface. *a*, Trabeculæ in cross and oblique section; *b*, splenic pulp; *c*, Malpighian body.

At occasional intervals areas occur in which the lymphoid cells are very much more closely packed than usual. These areas are called the **Malpighian bodies**, and give the organ a characteristic appearance.

The *blood-vessels* enter at the hilum of the organ, and proceed for some distance in the trabeculæ. From these, small branches proceed into the adenoid tissue, and frequently may be seen in the centers of the Malpighian corpuscles. Here they divide into very small arterioles, some of which open directly into rather large blood spaces in the splenic pulp, from which they may pass directly into veins without the intervention of true capillaries.

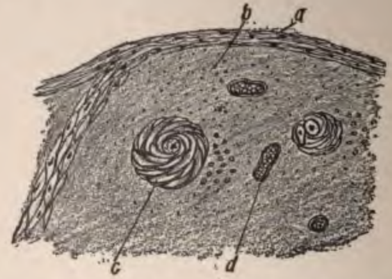

Fig. 29.—Thymus: *a*, Capsule; *b*, lymphoid tissue; *c*, corpuscle of Hassall; *d*, capillaries.

Small numbers of lymphatic vessels occur, mostly within the connective tissue of the capsule and trabeculæ, and surrounding the blood-vessels.

A few *nerve-fibers* are found, which are principally nonmedullated, and are distributed usually to the blood-vessels.

THYMUS.

In early life (up to the first year) the **thymus** is mostly epithelial in type, but as time goes on this is largely replaced by lymphoid tissue. The epithelium persists only as scattered, small, concentric masses (**Hassall's corpuscles**), containing a dozen or so flattened epithelial cells.

The gland is surrounded by a capsule of fibrous tissue, which sends down branching trabeculæ, dividing the lymphoid tissue incompletely into follicles. At the periphery of the follicles the lymphoid tissue is more densely packed with cells than at the center. This has led to a division of the follicles into a cortical (outer) and a medullary (inner) portion.

Blood-vessels and nerves are found in the trabeculæ, and send fine branches into the lymphoid tissue.

TONSILS.

The **tonsils** are two in number, situated one on each side of the base of the tongue. They are composed of several lymphoid follicles surrounded on their inner surface by a capsule of fibrous tissue and on their free outer surface by the stratified epithelium of the buccal mucous membrane.

At a number of places on the free surface of the tonsils the epithelium dips down into the lymphoid tissue, forming narrow fissures—the **crypts.** At these places the epithelium becomes infiltrated with lymphoid cells, until at the bottom of the crypts it fades away into the lymphoid tissue.

Blood-vessels, lymphatics, and a few nerves supply the tonsil and enter the organ through the capsule.

SEROUS CAVITIES AND MEMBRANES.

The **serous membranes** may be considered as the greatly expanded walls of lymph-vessels, and the **serous cavities** inclosed as greatly dilated lymph-spaces. In structure the serous membranes are composed of a single layer of thin, irregular, polygonal cells, placed edge to edge and united by cement substance, which rest upon a rather thin sheet of fibrous tissue. At irregular intervals small openings occur (the **stomata**), which are the mouths of lymphatics. Occasionally, a place is found at which the endothelial cells do not "match up" well. These spaces thus formed are filled up by cement substance, and are called the **pseudostomata.**

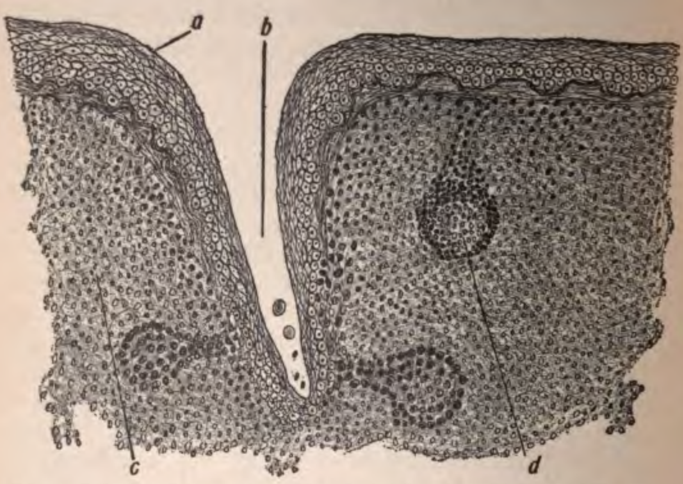

Fig. 30.—Tonsil: *a*, Epithelial surface; *b*, crypt; *c*, adenoid tissue; *d*, lymph-follicle.

The principal serous membranes of the body are the *pleura, pericardium,* and *peritoneum,* and the *synovial membranes of the tendons and joints.*

Structurally, the internal lining of heart, blood-vessels, and lymphatics would also come under this head.

MUCOUS MEMBRANES.

All cavities and passages in connection with the external air are lined with **mucous membranes.**

These consist of two essential parts—an *epithelial covering* and a *subepithelial fibrous coat.*

The epithelium may be either stratified or columnar, according to its location. Immediately under the epithelium the fibrous coat is usually specialized into a clear thin layer, called the "**basement membrane.**" Beneath the basement membrane, within the subepithelial fibrous tissue, in some localities a thin layer of smooth muscle—the **muscularis mucosæ**—occurs.

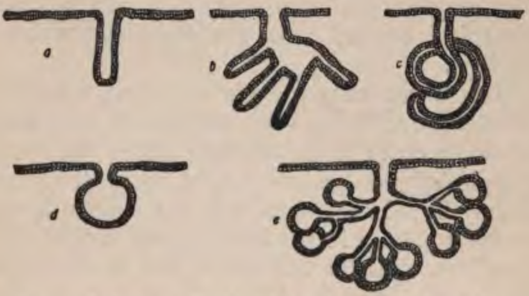

Fig. 31.—Types of glands: *a*, Simple tubular; *b*, compound tubular; *c*, coiled tubular; *d*, simple saccular; *e*, compound saccular, or racemose.

Along the course of the mucous membrane numerous **glands** occur. These are devices whereby a large secreting surface may be made to open upon a comparatively small area, and consist virtually of more or less complex invaginations of the epithelium.

Several types of glands are recognized:

1. **Simple tubular glands** are straight, narrow depressions into the subepithelial tissue, which are walled

by specialized epithelium continuous with that of the free surface. Examples of this type are found in the cardiac end of the stomach and in the crypts of Lieberkühn of the small intestine.

2. **Compound tubular glands** are similar in structure to the simple tubular, but branch. In some instances these branches divide and subdivide, producing an arborization of tubules all discharging their secretions eventually into the common duct. The glands of the pyloric end of the stomach and the mammary gland may be taken as examples.

3. **Coiled tubular glands** differ from the simple tubular only in the fact that they run a tortuous, usually spiral course. The sweat-glands are examples of this type.

4. **Simple saccular glands** are small, spheric cavities lined with secreting cells and having a small opening at their outer poles through which the secretion may be discharged upon the free surface. This type of gland may be said not to exist in the human body, but it occurs frequently in the lower forms of life, although some writers class the follicles of the ovary under this head.

5. **Compound saccular, alveolar,** or **racemose glands** resemble the compound tubular gland in arrangement, but the terminal secreting portion of the tubules dilates into saccules. The larger sebaceous glands and the lungs are constructed after this type.

QUESTIONS FOR CHAPTER VII.

119. What structures and organs are comprised in the lymphatic system?

120. Describe the lymph-vessels.

121. What are perineurium and perivascular lymphatics?

122. Name and describe the cells occurring in the lymph.

123. Describe diffuse adenoid tissue.
124. What are the lymph-follicles?
125. What are the lymph-nodes?
126. Describe the structure of a lymph-node.
127. To what system does the spleen belong?
128. Describe its capsule and trabeculæ.
129. Describe the Malpighian bodies of the spleen.
130. Describe blood and nerve supply.
131. Describe the thymus. What are Hassall's corpuscles?
132. What are the tonsils? Describe their structure.
133. What are serous membranes?
134. Where do they occur and what is their structure?
135. What are mucous membranes, and where do they occur? Describe their structure.
136. Name the types of glands and describe each.

CHAPTER VIII.

THE DIGESTIVE TRACT.

THE **mouth** is lined with mucous membrane, composed of stratified epithelium, upon the surface of which open the excretory ducts of numerous branched tubular glands. At the junction of the epithelium and the submucous tissue an irregular outline is presented, the projections of submucous fibrous tissue being called papillæ.

The **tongue** consists of a mass of voluntary muscle-fibers, running in various directions, surrounded by a layer of areolar tissue (the **submucosa**), and covered with stratified epithelium (the **mucosa**).

The muscular portion is made up of the geniohyoglossus, lingualis, and styloglossus muscles, and presents fibers running longitudinally, transversely, and vertically.

The submucous coat at its outer surface is thrown into marked papillæ, which are covered closely by epithelium.

Three types of papillæ are recognized:

1. **Filiform papillæ**, by far the most numerous, are narrow, conoid projections, which may have at their outer surface a number of smaller projections, called secondary papillæ.

2. **Fungiform papillæ**, not quite so numerous as the former, are larger, their bases are somewhat con-

stricted by the epithelium, and they contain secondary papillæ on their sides as well as at the outer surface.

3. The circumvallate papillæ are the largest and broadest of the three types. They occur in smaller numbers, and are usually found at the posterior portion of the tongue. They contain secondary papillæ at the top. At the sides, the epithelium dips down to form furrows or crypts, which make the papillæ appear to stand out from the surrounding tissue.

Embedded in the epithelium at the sides of the circumvallate papillæ are the *taste-buds.*

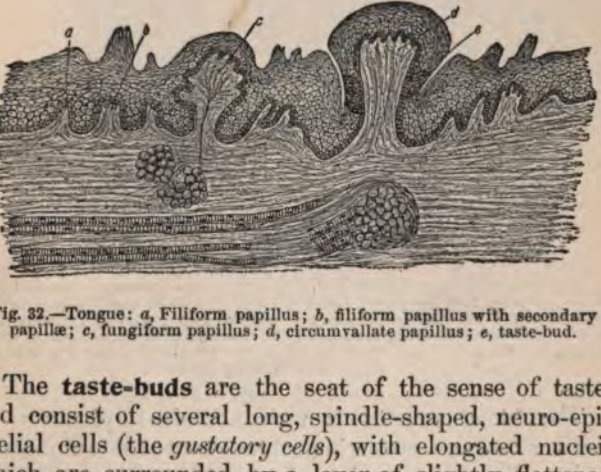

Fig. 32.—Tongue: *a*, Filiform papillus; *b*, filiform papillus with secondary papillæ; *c*, fungiform papillus; *d*, circumvallate papillus; *e*, taste-bud.

The **taste-buds** are the seat of the sense of taste, and consist of several long, spindle-shaped, neuro-epithelial cells (the *gustatory cells*), with elongated nuclei, which are surrounded by a layer of slightly flattened cells (the *cortical* or *tegment cells*), the whole forming small flask-shaped bodies, which are usually grouped side by side, vertical to the epithelial surface.

Besides the foregoing structures, the tongue contains a vertical partition, mostly of fibrous tissue (the *septum linguale*), which divides it into laterally symmetric halves. Numerous mucous and serous glands also occur in the submucous tissue.

The tongue is richly supplied with *lymphatics*, the larger vessels being situated deeply, the superficial ones forming a plexus under the mucosa and sending small branches up into the papillæ. Numerous lymph-follicles and areas of diffuse adenoid tissue occur in connection with the lymphatics, being especially numerous at the root of the tongue.

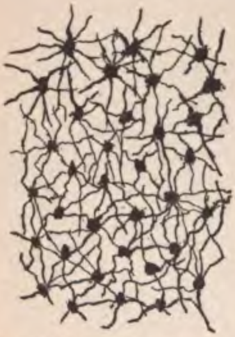

Fig. 33.—Ground section through dentin, cutting the dentinal tubules at right angles to their course, and showing the communicating branches connecting them.

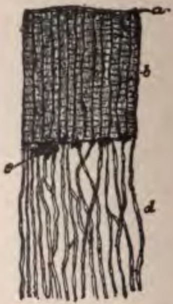

Fig. 34.—Transverse ground section of tooth at the junction of the enamel and dentin (diagrammatic): *a*, Enamel cuticle; *b*, enamel; *c*, interglobular spaces; *d*, dentin, showing dentinal tubules.

The **blood supply** is very abundant, plexuses of small arterioles occurring throughout the submucosa and sending branches into the papillæ and around the numerous glands.

The **mucous membrane** is richly supplied with *nerves*, both sensory and taste. They are mostly medullated fibers from the glossopharyngeal and lingual nerves. Numerous ganglia also occur along the course of the former.

THE TEETH.

Although the teeth vary considerably in shape and in general appearance, the same general structure is found in all.

The outer or exposed part of the tooth is called the **crown**; the portion embedded in the socket is called the **fang.** Between these, at about the edge of the gum, is a slightly constricted portion—the **neck.**

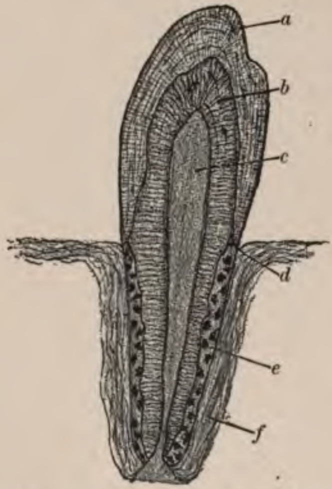

Fig. 35.—Tooth: *a*, Enamel; *b*, dentin; *c*, pulp-cavity; *d*, junction of enamel and cementum; *e*, cementum; *f*, alveolar periosteum.

The main bulk of the tooth is composed of the **dentin,** or **ivory.** This gives the form to the tooth, and incloses the **pulp-cavity,** which contains the **pulp.**

At the crown the dentin is covered by the **enamel.** At the fang it is covered by the **cementum,** except at the apex, where a minute canal penetrates to the pulp-cavity.

The **dentin** is composed of a hard, white, apparently homogeneous matrix, in which are numerous small (25 microns = $\frac{1}{1000}$ of an inch) canals—the **dentinal tubules.** These dentinal tubules originate in the pulp-cavity, and run a wavy course, more or less at right angles to the inner surface, through the dentin, and terminate at the juncture of the dentin and the enamel or cementum in irregular dilatations, called the **interglobular spaces.** Along their course many communicating branches occur, uniting the dentinal tubules.

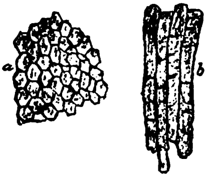

Fig. 36.—Enamel: *a*, Section parallel to surface, showing cross-sections of enamel prisms; *b*, longitudinal view of enamel prisms.

That portion of the matrix which forms the wall of the tubules being harder and denser than the main body, it has received the special name of **dentinal sheath.**

The **enamel** consists of closely arranged columns (the **enamel prisms**), running vertically to the free surface of the tooth, and held together by a very small amount of resistant, clear, cement substance. When isolated, these prisms are found to be four- to six-sided, and have a slightly irregular outline.

At the dentinal border of the enamel there occasionally occur between the enamel prisms small canals which open into the interglobular spaces.

At birth the enamel is covered by a thin membrane, the **enamel cuticle**, derived from the epithelial cells of the enamel organ; this, however, soon wears off.

The **cementum** consists of concentric layers of osseous tissue containing many lacunæ, with their radiating canaliculi, which contain bone-corpuscles and communicate with the interglobular spaces.

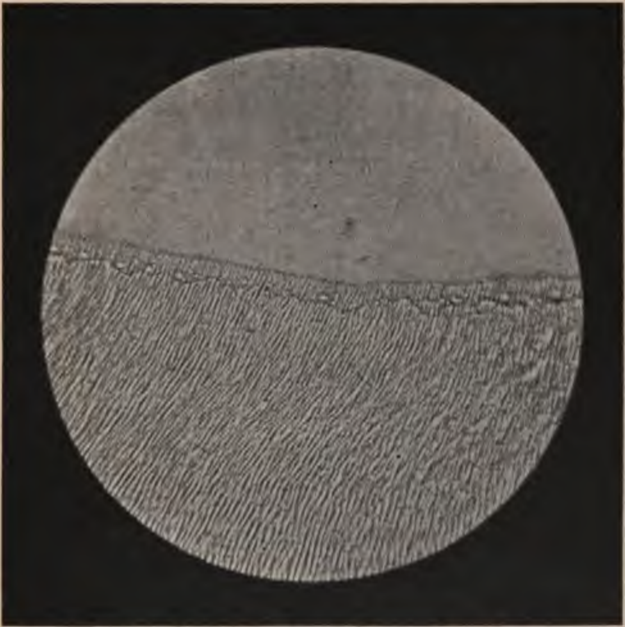

Fig. 37.—Dentin at edge of pulp-cavity, showing open ends of dentinal tubules through which extend prolongations of the odontoblasts—the dentinal fibers. Photograph made from a ground section of tooth.

Haversian canals are absent, excepting occasionally in the thickest portions.

The cementum is surrounded by a dense layer of connective tissue (the **periodontal membrane**), which is virtually a periosteum.

The **tooth-pulp** is a mass of undeveloped connective tissue, consisting mostly of stellate or irregular connective-tissue cells, with nerves and blood-vessels, which fill the pulp-cavity.

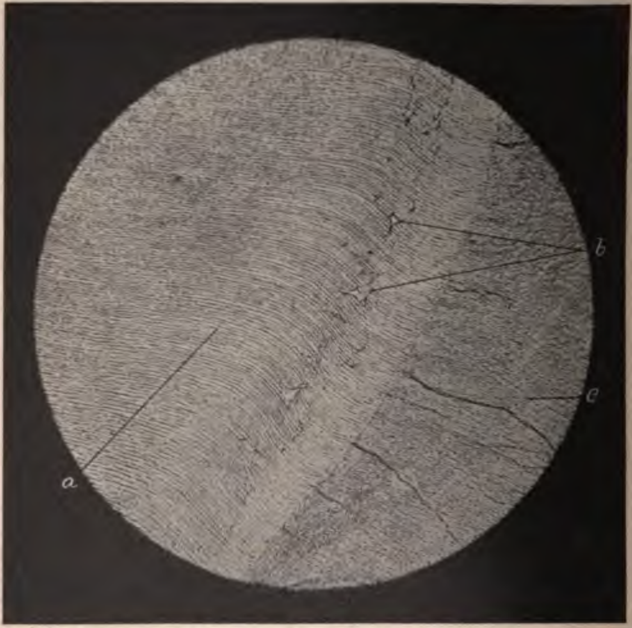

Fig. 38.—Junction of dentin and enamel: *a*, Dentin, showing dentinal tubules and (*b*) interglobular spaces; *c*, enamel. Photograph from ground section of tooth.

The portion of the pulp in contact with the dentin is made up of elongated cells (the **odontoblasts**), which send long processes into the dentinal tubules.

These processes usually extend the whole length of the tubule, and are called the **dentinal fibers.**

The Development of Teeth.

Both the epiblast and mesoblast contribute to the formation of the teeth.

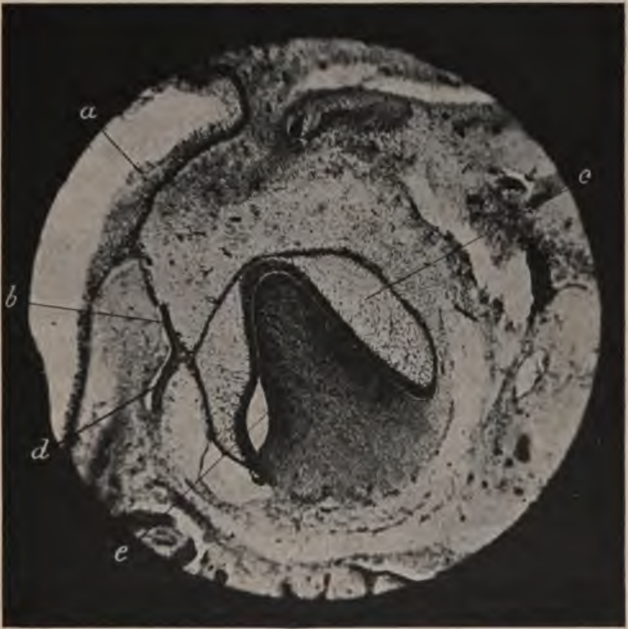

Fig. 39.—Developing tooth: *a*, Stratified epithelium of buccal cavity, sending down (*b*) cord of cells—the dentinal ridge; *c*, greatly expanded mass of epithelial cells forming the enamel organ; *d*, small offshoot of epithelium, which later will develop into the enamel organ of the permanent tooth; *e*, papillus.

The epithelium over the primitive jaw becomes thickened, and grows down into the subjacent tissue to form the **dental ridge.** From the lower outer border of this, flask-shaped masses of cells (**dental bulbs**) grow (one for each milk-tooth), which subsequently become hollow on their under surface and cover a conoid upgrowth of connective-tissue cells (the *papillæ*).

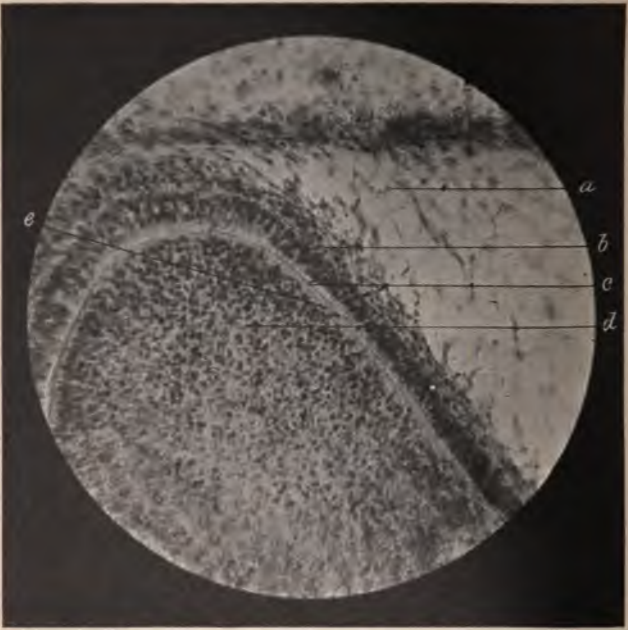

Fig. 40.—Developing tooth, more highly magnified: *a*, Outer portion of enamel organ; *b*, inner layer of columnar cells of enamel organ, which are just beginning to secrete; *c*, enamel; *d*, portion of papillus, the outer layer of which is composed of odontoblasts which are just beginning to secrete; *e*, dentin in contact with the enamel.

The dental bulbs continue to expand, their inner surfaces assuming the form of the crown of the tooth, and the inner layer of cells becoming columnar.

Each of these columnar cells secretes an enamel prism, and the bulb is now called the **enamel organ.** While this has been in progress, the outer cells of the papillæ have elongated to form the *odontoblasts*, which deposit the dentin. Thus it will be seen that the enamel is deposited outward, the dentin inward. The remains of the papillæ become the tooth-pulp.

The permanent teeth are developed similarly from secondary dental bulbs springing diagonally downward from the neck of the milk-tooth bulbs.

The cementum is deposited later by the alveolar periosteum.

THE ESOPHAGUS.

The **esophagus** has four layers—mucous, submucous, muscular, and fibrous.

The **mucous coat** consists of stratified epithelium resting upon a basement membrane which is thrown up into papillæ. At the outer edge of the basement membrane is found a very narrow layer of smooth muscle —the muscularis mucosæ.

The **submucous coat** is of loose fibrous tissue, and contains numerous blood-vessels, lymphatics, and nerves, besides scattered mucous glands, which discharge into the lumen of the esophagus.

The **muscular coat** consists of two layers—an inner (circular) and an outer (longitudinal)—throughout its length, the upper third being composed of voluntary muscle-fibers, which are gradually replaced below this point by smooth muscle.

The **fibrous coat** is a thin layer of rather dense, white, fibrous tissue, which may also contain a few fibers of yellow elastic tissue.

THE STOMACH.

The **stomach** presents two portions for consideration: viz., the *cardiac* or upper and the *pyloric* or lower ends.

The **cardiac end of the stomach** comprises four coats—mucous, submucous, muscular, and serous.

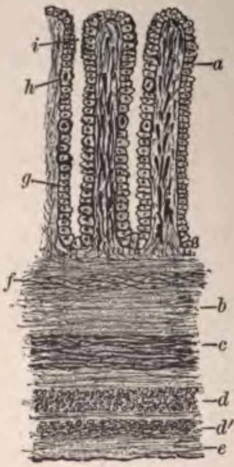

Fig. 41.—Cardiac end of stomach: *a*, Mucous coat; *b*, submucous coat; *c*, *d*, *d′*, longitudinal, circular, and oblique muscular coats; *e*, serous coat; *f*, muscularis mucosæ; *g*, chief cells; *h*, acid cells; *i*, opening of gastric gland on free surface of stomach.

The *mucous coat* is continuous with that of the esophagus, and, like the latter, has a basement membrane and muscularis mucosæ. The epithelium, however, is thickly studded with simple tubular glands, opening upon the free surface. In these glands two types of cells are found—*chief* or *peptic*, and *parietal* or *acid*. The chief cells, which are more numerous and smaller, were supposed to be the pepsin-secreting elements.

The parietal cells are relatively large, and have well-marked, large cell bodies, which stain deeply in almost all anilin stains. They were supposed to be the hydrochloric-acid-secreting element.

The submucous coat consists of loose fibrous tissue containing many blood-vessels, lymphatics, and nerves. Occasionally, small areas of diffuse adenoid tissue may occur. This coat is frequently thrown into ridges carrying the mucous coat above it and forming the rugæ.

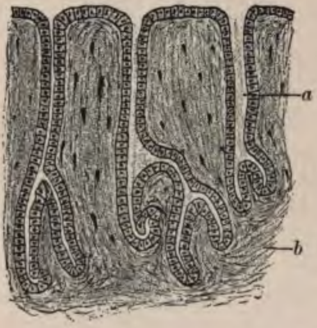

Fig. 42.—Mucous coat of pyloric end of the stomach: *a*, Branched tubular gland; *b*, submucous coat.

The muscular coat consists of three layers of smooth muscular fibers—an inner *circular*, a middle *longitudinal*, and an outer *incomplete oblique* layer.

The serous coat is a reflection of the peritoneum, and is made up of a delicate sheet of fibrous and yellow elastic tissue, covered on the outer side by a single layer of endothelial cells.

The **pyloric end of the stomach** differs from the cardiac end chiefly in the mucous and muscular coats.

The glands studding the mucous coat (pyloric glands) are slightly further apart than in the cardiac end. They are further characterized by branching at their lower ends, to terminate in two or three tortuous offshoots. Only one type of cell is present in these glands, the parietal or acid cells being confined entirely to the cardiac portion.

The outer or oblique muscular layer is usually entirely absent also. The masses of adenoid tissue in the submucosæ (solitary follicles) are usually a trifle more numerous here than in the cardiac portion.

THE INTESTINES.

The intestines contain four coats throughout their entire length: viz., mucous, submucous, muscular, and serous. The mucous coat is frequently thrown into transverse ridges, which are called the *valvulæ conniventes.* Structurally, we may recognize the *duodenum, small intestine, large intestine,* and *appendix.*

The **small intestine** has projecting from its mucosa small, finger-like projections, called the **villi,** which are often club-shaped. These villi are covered with a single layer of columnar epithelial cells, which often exhibit the goblet form. Dipping down into the submucous coat from between the villi are simple tubular glands, the **crypts of Lieberkühn,** which secrete the succus entericus.

Directly under the epithelium is a flat layer of connective-tissue cells, called the **endothelium of Débove,** which in turn rests upon a membrana propria of fibrous tissue. At the inner border of this is the muscularis mucosæ, which extends throughout the intestine. Within the villi is found a small lymphatic radical (the **lacteal**) surrounded by a network of capillaries.

The adenoid tissue is especially well developed in the small intestine, lymphoid follicles frequently coalescing to form the **agminated follicles,** or **Peyer's patches.**

The **submucosa** of the intestine is similar to and continuous with that of the stomach.

The **muscular coat** consists of two layers of smooth muscle, an inner circular and an outer longitudinal, continuous with the inner two muscular layers of the stomach.

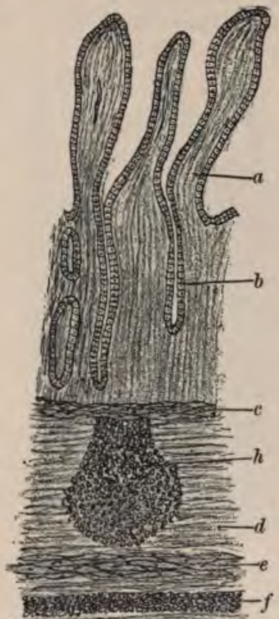

Fig. 43.—Small intestine: *a*, Villus; *b*, crypt of Lieberkühn; *c*, muscularis mucosæ; *d*, submucous coat; *e*, *f*, circular and longitudinal muscular coat; *g*, serous coat; *h*, lymph-follicle of Peyer's patch.

The **duodenum** differs from the other parts of the small intestine in having the **duodenal glands**, or **Brunner's glands.**

These are good-sized, very compound, tubular glands, situated in the submucosa, which communicate with the lumen of the intestine through a slender duct, which discharges the secretions between the villi.

The **large intestine** differs from the small chiefly in the *absence of the villi.* The crypts of Lieberkühn, however, persist, but are rather short and well separated. At the *anus* the epithelium becomes stratified.

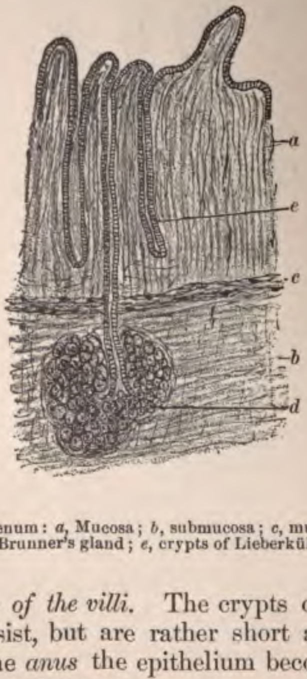

Fig. 44.—Duodenum: *a*, Mucosa; *b*, submucosa; *c*, muscularis mucosæ; *d*, Brunner's gland; *e*, crypts of Lieberkühn.

The **rectal valves** are three or more in number, appearing as semilunar folds projecting into the lumen of the rectum. In structure they have the general characteristics of the large intestine and the same coats with the exception of the peritoneal which is absent and replaced by the perirectal fascia. The *mucosa* is somewhat thickened and the crypts more closely packed than in the large intestine. The *lymphoid tissue* constituting solitary follicles is also quite abundant.

The *submucosa* occupies the main bulk of the center of the valves and does not differ greatly from that in other portions of the intestines.

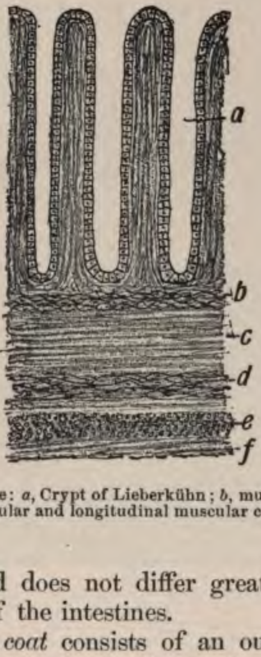

Fig. 45.—Large intestine: *a*, Crypt of Lieberkühn; *b*, muscularis mucosæ; *c*, submucosæ; *d*, *e*, circular and longitudinal muscular coat; *f*, serous coat.

The *muscular coat* consists of an outer longitudinal and an inner circular layer of smooth muscle. At the lower edges of the valves the muscular coats span the base, but as the middle, wider portion of the valve is reached the circular muscular fibers and a part or all of the longitudinal fibers dip down into the body of the valve; that is, between the two adjacent submucous coats. It will be seen that, in this case, a contraction of the muscular fibers will force the valve into the lumen of the rectum, thus giving the valves what might be described as "erectile" characteristics.

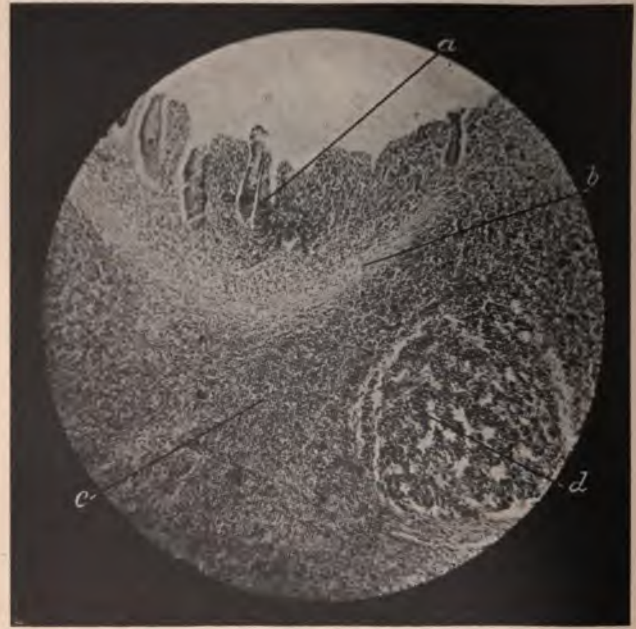

Fig. 46.—Transverse section of portion of the appendix, showing mucous and part of submucous coats: *a*, Atrophic crypts of Lieberkühn; *b*, fibers of muscularis mucosæ; *c*, submucosa, consisting almost exclusively of lymphoid tissue; *d*, large lymph follicle identical with solitary follicles of large intestine.

The **appendix vermiformis** has the same general arrangement as the large intestine. In the mucosa, however, the crypts of Lieberkühn are shorter and less numerous. The lymphoid tissue is very prominent, usually encroaching upon the crypts and oftentimes displacing some of the lower epithelial cells, and forming a complete layer around the mucosa. A true basement membrane is absent or incomplete and the muscularis mucosæ is frequently interrupted.

The muscular coats are relatively very well developed.

The *blood supply* of both stomach and intestines follows the same plan. The afferent arteries pierce the outer two coats and give off large branches in the submucosa. From these, two sets of capillaries originate, one supplying the muscular and serous coats, the other being distributed to the mucosa, where it forms a subepithelial network and also surrounds the glands.

The *nerves*, which are both medullated and nonmedullated, pierce the serous coat and the outer muscular coat and form a complex network between the longitudinal and circular muscular coats, beset with microscopic ganglia. This network is called the **plexus of Auerbach**, and sends branches to the serous and outer muscular coats. Numerous branches are also given off to the submucosa, where they form another finer network (the **plexus of Meissner**), which in turn gives off very fine branches to the epithelium, glands, and villi.

Lymphatics are very plentiful, beginning as blind canals situated between the glands, as lacteals within the villi, around the lymph-follicles, and in the muscular tissue. These canals communicate with a large plexus of moderate-sized lymph-vessels, which accompany the blood-vessels in the submucosa, and eventually pierce the muscular and serous coats to run within the peritoneal cavity

THE LIVER.

The **liver** is composed of five lobes, which are enveloped by a thin covering of *fibrous tissue.*

This fibrous tissue, which is very scanty and incomplete in man, but well marked in the hog, extends from the surface down through the substance of the organ (the **capsule of Glisson**), dividing it up into irregular **lobules,** which appear roughly hexagonal in sections.

The lobules are composed of tortuous rows of polyhedral, granular cells (**hepatic cells**), radiating from the center toward the periphery of the lobule.

The liver receives blood from two sources: viz., the *portal vein* and the *hepatic artery.* These vessels enter the organ at the transverse fissure and divide into small branches, which run between the lobules in the capsule of Glisson and are called the *interlobular veins* and *arteries* respectively.

The interlobular vein now sends a network of capillaries (the *intralobular capillaries*) between the rows of hepatic cells, to collect again in a small vein at the center of the lobule (the *central* or *intralobular vein*).

The interlobular branches of the hepatic artery divide up into capillaries, which are distributed to the fibrous structures in the capsule of Glisson, and eventually enter directly into the intralobular capillaries, so that the blood in the central vein is really a mixture of that brought to the liver by both the hepatic artery and the portal vein.

A number of central veins unite to form larger veins (the *sublobular veins*), and these in turn unite to form the *hepatic veins,* which conduct the blood from the liver to the vena cava.

Between the individual liver-cells in the center of the radiating columns are minute branching vessels (the *bile capillaries*), which run to the periphery of the lobules and there empty into the *interlobular bile-ducts.* These accompany the interlobular arteries and veins in Glisson's capsule, and the three vessels, with their surrounding fibrous tissue, are termed the **portal canals.** The bile-ducts constantly join other bile-ducts, until they finally leave the liver by two large ducts, which fuse to become the hepatic duct.

The bile-ducts are lined by a single layer of columnar epithelium, surrounded by a wall of fibrous tissue interspersed with fibers of yellow elastic and smooth muscular tissue and supported by some loose areolar tissue.

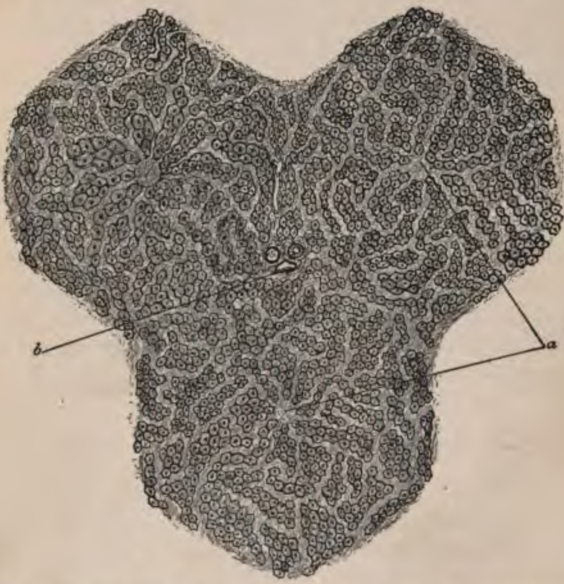

Fig. 47.—Three lobules of liver: *a*, Central veins; *b*, portal canal containing artery, vein, and bile-ducts.

The *lymphatics* of the liver accompany the blood-vessels as perivascular spaces, the *superficial lymphatics* occurring around the vessels of the capsule. The *deep plexus* surrounds the interlobular vessels, and possibly the intralobular capillaries.

The *nerves* of the liver are both medullated and non-medullated. They follow the course of the hepatic artery in the capsule of Glisson. Small ganglia occasionally occur near the edge of the lobule, but the exact termination of the fibers is not known.

The **gall-bladder** consists of three coats. The *mucous* or *internal coat* is composed of columnar epithelium continuous with that of the hepatic duct. External to this is the *middle* or *fibrous coat*, which, besides white fibrous tissue, contains numbers of longitudinal and transverse smooth muscle-fibers.

The *outer* or *serous coat* is derived from the peritoneum.

The inner surface is thrown into small ridges, called rugæ, and is usually covered by a viscid secretion from the mucous lining.

THE SALIVARY GLANDS.

The salivary glands are the **parotid,** the **submaxillary,** and the **sublingual glands,** and the **pancreas.** They all belong to either the compound tubular or the racemose type of gland, and are surrounded by a *capsule* of fibrous tissue, which sends septa down into the glands, dividing it into *lobes*. The lobes are further subdivided by smaller septa of fibrous tissue into lobules. The *main duct* of the gland enters at the hilum and divides into numerous branches, one of which is distributed to each lobe (the *interlobar duct*). These further divide, sending a branch (the *interlobular ducts*) to each lobule, where they again divide into the *intra-*

lobular ducts, or *salivary tubes of Pflüger*, which in turn continue for a way as the *intermediate tubes*, and terminate in the secreting portion of the gland, the **acini**, or **alveoli.**

All the *ducts* are lined with a layer of columnar epithelium, which rests on a basement membrane. In some of the main ducts a second layer of low cells is found between the columnar cells and the basement membrane. External to the basement membrane is a fibrous coat, which may contain some fibers of yellow elastic tissue and, in the larger ducts, smooth muscle-fibers.

The *acini* vary in different glands from saccular to club-shaped or tubular. They are lined by a single layer of epithelial cells, broader and larger than those lining the ducts, which rest upon a membrana propria, or basement membrane.

According to the character of the *secretion* and the *general structure* of the *acini*, the salivary glands are divided into the *serous*, *mucous*, and *mixed glands*.

The **serous glands** secrete a thin, watery, albuminous saliva. The alveoli are usually small and of the tubular variety.

The cells are opaque and markedly granular, and rest upon a relatively small basement membrane. The nuclei are usually round, and are placed about one-third the width of the cell from the basement membrane. In the true serous glands the "demilunes" are absent.

The **mucous glands** secrete a thick, viscid fluid (mucus). The *alveoli* are usually larger than those in the serous glands, and are saccular or flask-shaped. The *cells* are larger, transparent, but slightly granular, have a well-developed basement membrane, and stain but slightly. The *nuclei* are usually flattened, and are placed close to the basement membrane.

In many alveoli we find, besides the large clear cells just described, thin, granular cells, or groups of cells, crescentic in form, and situated at the periphery of the acini, against the basement membrane. These usually have a spheric nucleus, and are known as the *demilunes of Heidenhain*, or the *crescents of Gianuzzi.*

The **mixed glands,** or **seromucous glands,** may have some acini of the serous type and some of the mucous, or some acini may contain cells of both kinds. It has been claimed that the demilunes could be considered as representing occasional serous cells situated peripherally in a mucous gland.

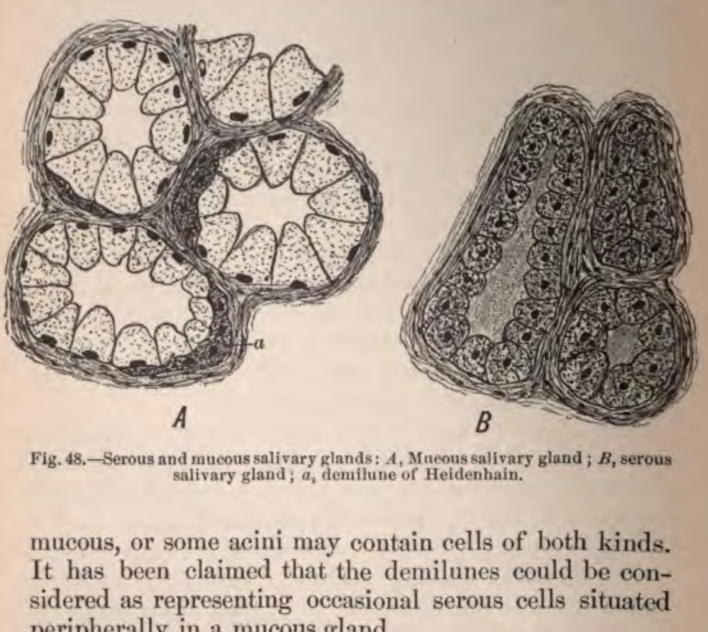

Fig. 48.—Serous and mucous salivary glands: *A*, Mucous salivary gland; *B*, serous salivary gland; *a*, demilune of Heidenhain.

The *blood supply* of the glands is very abundant, the arteries accompanying the excretory ducts to a point near the acini, where they branch into a network of capillaries, which closely surround the basement membrane of the acini, and reunite to form the veins, which return parallel to the arteries.

The *larger lymphatic vessels* are found with the arteries in the interlobular connective tissue. These send along the course of the ducts branches which terminate in numerous irregular clefts or spaces around and between the acini.

Nerves are plentiful, and consist of medullated and nonmedullated fibers, with numerous small ganglia.

The ultimate distribution of the nerve filaments is unknown, having been traced positively only as far as the basement membrane of the alveoli.

The Parotid Gland.

The parotid gland is a typical serous gland, and possesses the characteristics previously described under that head.

The excretory duct (Stenson's duct) is large, has thick walls of fibro-elastic tissue, and is lined by a double layer of epithelium. Its smaller branches are lined with a single layer of columnar cells, which present a distinctly striated appearance at their free edges, and are hence called rod epithelium.

Between the intralobular ducts and the acini intermediate or intercalated tubules occur. These are small tubules lined with flattened cells.

The Pancreas.

The pancreas is a gland of the serous type, and resembles the parotid gland so closely as to have been called "the abdominal salivary gland." It differs, however, from the parotid in the following features:

The pancreatic duct (or main duct of the gland) branches directly to form the *intermediate tubules* without the intervention of the intralobular ducts, or salivary tubes of Pflüger, which in the parotid are lined with rod epithelium and are quite prominent.

The *acini* are longer and narrower, as a rule, than those of the parotid.

The *secreting cells* are more columnar, narrower, and their nuclei are usually slightly farther from the peripheral edges of the cells.

The cells also contain distinct, highly refracting granules (the **zymogen granules**), situated mostly at the margin of the cell-body next to the lumen. The number of granules and the extent of the granular zone in the cell depend upon the state of activity of the gland, being least in evidence just as digestion begins.

The development of the pancreas is not homogeneous, but throughout the organ are found certain small, denser areas, well supplied with blood-vessels, which are undeveloped lobules or acini.

These areas possess vaguely the type of the rest of the organ, and have received the special name "**bodies of Langerhans.**"

The Sublingual Gland.

The sublingual gland in man affords a typical example of a mucous gland, having all the characteristics previously described under that head.

Its main duct, the ductus sublingualis, or duct of Bartholin, is lined with a double layer of columnar epithelium, which rests upon the usual membrana propria of fibro-elastic tissue.

This duct branches to form the intralobular or mucous tubes, which pass directly into the acini, there being no "intermediate" tubules in this gland.

The fibrous tissue between the acini is quite scanty, and usually contains many wandering connective-tissue cells.

The Submaxillary Gland.

In man the submaxillary gland is of the mucoserous or mixed type. The main duct, or *duct of Wharton*, divides in the usual manner until the intermediate tubules are reached, some of which terminate in the acini of the serous type; others, in the acini of the clear mucous type.

QUESTIONS FOR CHAPTER VIII.

137. Describe the mucous membrane of the mouth.

138. Of what tissue is the tongue composed?

139. Name the types of papillæ in the tongue.

140. What are the taste-buds? Describe them.

141. What is the lymphatic supply of the tongue? the blood supply? the nerve supply?

142. Describe the gross structure of the tooth.

143. What is dentin? Describe it. What is the enamel? the cementum? the tooth-pulp?

144. What layers of the embryo contribute to the development of the teeth?

145. What is the dental ridge?

146. What are the odontoblasts?

147. Describe the process of tooth development.

148. Name the four layers of the esophagus. Describe each.

149. What two portions of the stomach are considered histologically?

150. Name the four layers of the stomach.

151. Describe the mucous coat of the cardiac end of the stomach; the submucous coat; the muscular coat; the serous coat.

152. How does the pyloric differ from the cardiac end of the stomach?

153. Name the four coats of the intestine.

154. What portions of the intestine do we recognize structurally?

155. What are the villi?

156. What are the valvulæ conniventes?

157. Describe the mucous membrane of the small intestine.

158. What is the endothelium of Débove?

159. What are the lacteals?

160. What are Peyer's patches?

161. Describe the submucous coat of the small intestine.

162. What are crypts of Lieberkühn?

163. Describe the muscular coat of the small intestine.

164. What are Brunner's glands, and where do they occur?

165. How do the large intestines differ from the small?

166. Describe the structure of the appendix vermiformis.

167. Describe the blood supply of the stomach and the intestines; the nerve supply; the lymphatics.

168. Into what is the liver divided?

169. What is the capsule of Glisson, and of what is it composed?

170. Of what are the lobules composed?

171. Describe fully the blood supply to the liver.

172. Where do the bile capillaries originate? Describe their course.

173. Describe the portal canal.

174. Describe the structure of a bile-duct.

175. Describe the lymph supply of the liver.

176. Describe the nerve supply of the liver.

177. Describe the structure of the gall-bladder.

178. Name the salivary glands.

179. Outline their general structure.

180. What is the main duct? What are the interlobar ducts? the salivary tubes of Pflüger? the intermediate tubes? the alveoli?

181. What is the structure of the ducts?

182. What is the characteristic of a serous gland? of a mucous gland? of a mixed gland?

183. What are the demilunes?

184. Describe the blood supply of the salivary glands; the lymphatic supply; the nerve supply.

185. Describe the special characteristics of the parotid gland.

186. Describe the special characteristics of the pancreas.

187. What are the bodies of Langerhans?

188. What type of gland is the sublingual? Describe it.

189. What type of gland is the submaxillary? Describe it.

CHAPTER IX.

THE URINARY TRACT.

THE **kidney** is covered by a capsule of fibrous tissue, and upon longitudinal section is seen to be composed of two distinct portions.

The outer or *cortical portion* is granular in appearance and comprises about one-third of the organ. The inner or *medullary portion* constitutes the remaining two-thirds of the organ, and is seen to be composed of a number (from ten to fifteen) of pyramidal masses (the **pyramids of Malpighi**), with their bases at the inner edge of the cortex, and their apices pointing into the sinus, constituting the *papillæ*.

They are finely striated radially, owing to the alternate arrangement of the uriniferous tubules and blood-vessels which compose them. Usually small extensions of cortical substance, called the cortical columns, or **columns of Bertini,** project down between the pyramids of Malpighi, separating them one from another.

At intervals along the junction of the cortex with the Malpighian pyramids projections from the latter extend into the cortical substance. These are called the **medullary rays,** or **pyramids of Ferrein,** and consist of continuations of the striations composing the Malpighian pyramids. That portion of the cortex situated between the pyramids of Ferrein has received the name of the **labyrinth,** on account of the tortuous course which its component tubules take (being composed chiefly of the first and second convoluted tubules, a description of which follows).

At the side of the kidney opposite the cortex there is a marked depression, called the **hilum**, at which point it flares out into a funnel-shaped tube (the **pelvis**) and expands into a central cavity, called the **sinus.**

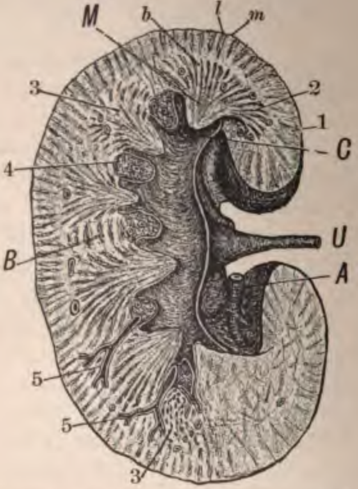

Fig. 49.—Kidney, longitudinal section, exhibiting general relations of microscopic details (after Piersol): *A*, Renal artery; *U*, ureter; *C*, one of the calyces, into which a papilla projects; 1, cortex containing labyrinth (*l*) and medullary rays (*m*); 2, medulla; *M*, Malpighian pyramids, some obliquely cut at 3, 3; *b*, boundary layer; *B*, columns of Bertini; 4, masses of adipose tissue; 5, 5, branches of renal artery (after Henle).

The sinus has several branches or divisions, into which project the papillæ (the **infundibulæ,** or **calyces**).

URINIFEROUS TUBULES.

The histologic units of the kidney are the uriniferous tubules. These tubules begin as closed, spheric expansions (the **glomeruli** or **Malpighian bodies**) in the labyrinth of the cortex. At the end of the glomerulus a slight constriction occurs, called the **neck.** Next the tubule increases in size slightly and pursues a wavy course, entering the area of the medullary ray (the **first** or **proximal convoluted tubule**). Here it turns downward in a spiral course (the **spiral tubule**), until it reaches the lower border of the medullary ray, and enters one of the Malpighian pyramids. At this point the diameter becomes much smaller and the tubule descends in nearly a straight line as the *descending limb of Henle's loop.* When well down in the Malpighian pyramid, the tube expands somewhat, and then turns abruptly upward (the **loop of Henle**) and ascends in a straight line, nearly parallel to the descending tubule, until it is well up into the medullary ray (the *ascending limb of the loop of Henle*), when it expands still more, reenters the labyrinth, and follows a very irregular course for a short distance (the *irregular* or *zigzag tubule*).

The convolutions of the zigzag tubules become more regularly curved (the *second* or *distal convoluted tube*), and the tubule again enters the medullary ray. Here it forms a slight arch (the *arched collecting* or *junctional tubule*) and joins a large collecting tubule or the *tubule of Bellini,* which runs straight down toward the pelvis of the kidney, joining other similar collecting tubules to form *principal tubules,* several of which unite to form a *papillary duct,* which terminates at the end of one of the papillæ. A single papilla will contain about two hundred papillary ducts.

A Malpighian body is composed of a small afferent arteriole, which immediately branches into a spheric tuft of capillaries, which reunite to form one or, rarely, more efferent arterioles, which emerge beside the afferent vessel.

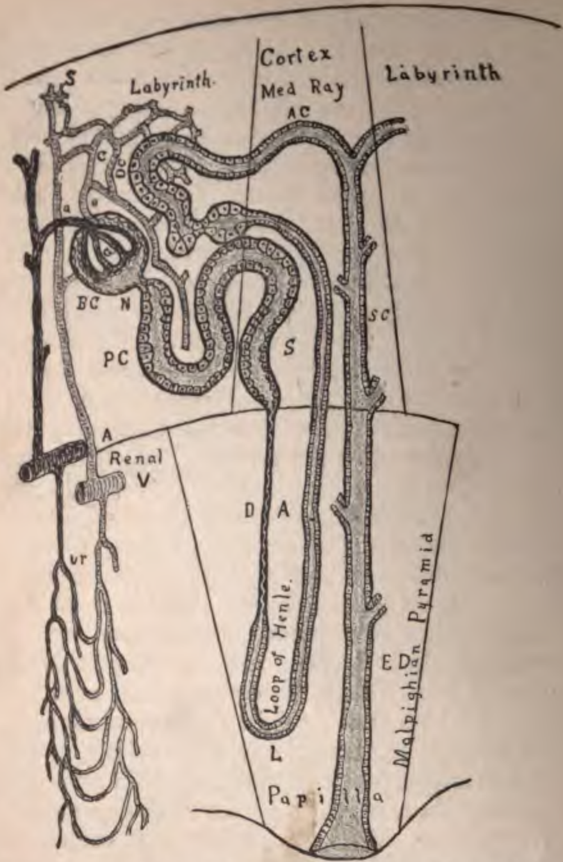

Fig. 50.—Diagram of kidney, showing the course of uriniferous tubules and of the blood-vessels (after Piersol); for convenience, the medulla is represented as greatly shortened. The various divisions of the tubule—Bowman's capsule, neck, proximal convoluted, spiral, descending and ascending limb of Henle's loop, irregular, distal convoluted, arched collecting, straight collecting, and excretory duct—are indicated by their initial letters: *a*, *e*, *c*, respectively the afferent, efferent, and capillary blood-vessels; *s*, stellate vein; *v r*, vasæ rectæ.

Closely surrounding this tuft and dipping down between the capillaries is a thin layer of fibrous tissue called the *capsule of Bowman*, which serves as a basement membrane for a layer of flat cells, which are continuous with the cells lining the uriniferous tubules.

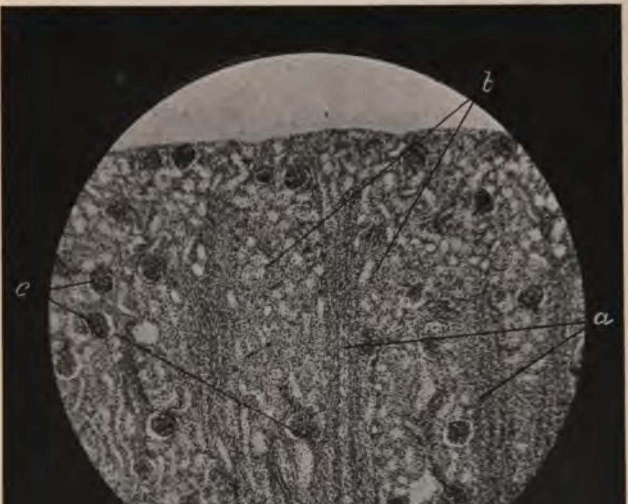

Fig. 51.—Cortical portion of kidney: *a*, Medullary rays; *b*, labyrinth; *c*, glomeruli.

At the upper part of the Malpighian body, where the arteriole enters, the capsule of Bowman with its layer of cells bends sharply around upon itself, and descends, inclosing a very narrow space, which is the beginning of the lumen of the tubule. The tuft, therefore, lies entirely on the outside of the tubule, as though it had been thrust into a hollow sphere, causing one side to be invaginated into the other.

The *uriniferous tubules* are surrounded by a basement membrane, continuous with the capsule of Bowman, upon which, internally, rests a single layer of epithelial cells, continuous with those lining the Malpighian body.

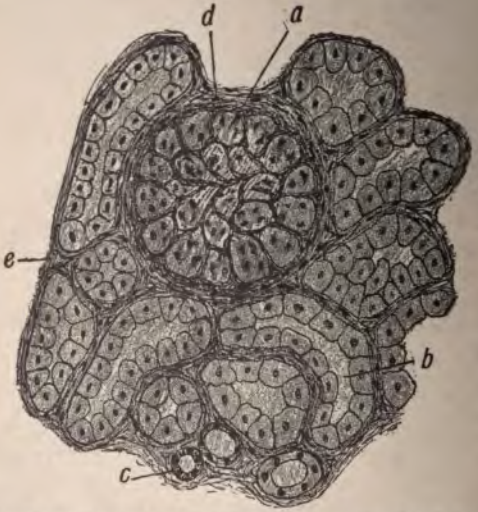

Fig. 52.—Kidney in section: *a*, Glomerulus; *b*, cross-section of convoluted tubule; *c*, cross-section of Henle's tubule; *d*, capsule of Bowman; *e*, fibrous tissue between tubules.

The size and character of these cells vary according to the part of the tubule in which they are found. The *glomerulus* is about 0.2 mm. ($\frac{1}{125}$ of an inch) in diameter, the cells lining it being *squamous*. At the neck the diameter diminishes to 25 microns ($\frac{1}{1000}$ of an inch), the epithelium being of a low cuboid form. The *proximal* and *distal* convoluted tubules are similar, being 50 microns ($\frac{1}{500}$ of an inch) in diameter and lined with columnar cells. These cells are of moderate size, being about 12.5 microns ($\frac{1}{2000}$ of an inch) high. In favorable preparations they are seen to contain fine striations at the outer border, and to be finely granular in that portion next to the lumen. The *spiral tubule* diminishes slightly in size to 40 microns ($\frac{1}{625}$ of an inch); the epithelium resembles that of the convoluted tubules, with perhaps a slightly plainer striation. The

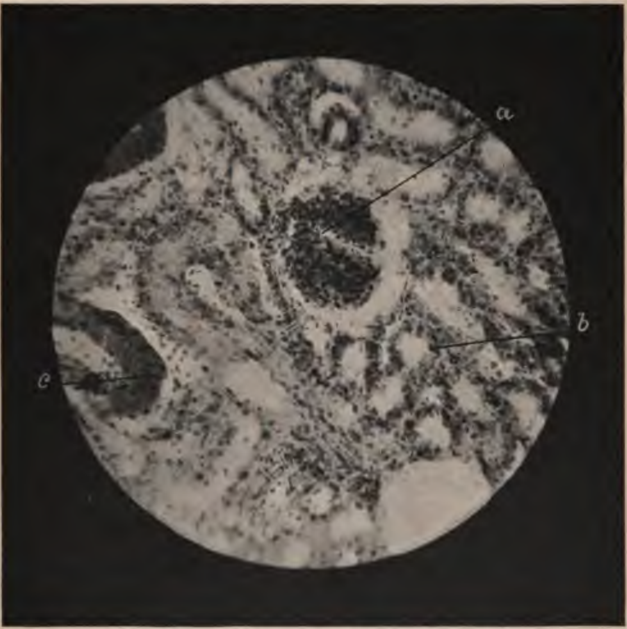

Fig. 53.—Section of kidney: *a*, Glomerulus; *b*, uriniferous tubules in transverse section; *c*, portion of convoluted tubule.

epithelium at the *descending limb of Henle's loop* becomes very much flattened, being only about 3 microns ($\frac{1}{8400}$ of an inch) in thickness, the total diameter of the tube at this place measuring about 10 microns ($\frac{1}{2500}$ of an inch). In the *loop* and *ascending limb of Henle* the cells increase in size to 6 microns ($\frac{1}{4200}$ of an inch), the total diameter of the tube being 25 microns ($\frac{1}{1000}$ of an inch). No definite size can be ascribed to the *irregular tubule;* it varies, however, between 35 and 60 microns ($\frac{1}{700}$ and $\frac{1}{400}$ of an inch). The cells resemble those of the spiral tubule, the nuclei being more oval and nearer the lumen. The *tubes of Bellini* have the general characteristics of the second convoluted tubule, being, however, slightly narrower (40 microns, or $\frac{1}{625}$ of an inch). The *principal tubes* and *papillary ducts* vary in size up to 250 microns ($\frac{1}{100}$ of an inch).

It will be seen that, with the exception of the glomerulus, in a cross-section of a tubule the cell on either side and the lumen each occupy about one-third of the entire diameter.

BLOOD SUPPLY.

The blood enters the kidney at the hilum through the *renal artery,* which passes just within the mucosa of the pelvis, sending branches (*interpyramidal arteries*) up between the Malpighian pyramids (in the columns of Bertini) and a few very small branches to the adjacent tissues. The large branches proceed upward to the juncture of the medullary and cortical portions, where they turn nearly at right angles and form arches over the top of the Malpighian pyramids, called the **arterial arcade.** From the arterial arcade two series of smaller branches arise : one series, the *interlobular arte-*

ries, running straight toward the periphery, following the outer border of the labyrinth; the second series, the *arteriæ rectæ*, running toward the pelvis, into the Malpighian pyramids.

The **interlobular arteries** give off into the labyrinth numerous lateral branches, which enter the glomeruli as *afferent arterioles*. These form a small plexus within the glomerulus and emerge as the *efferent arterioles*, break up into capillaries, and course around between the

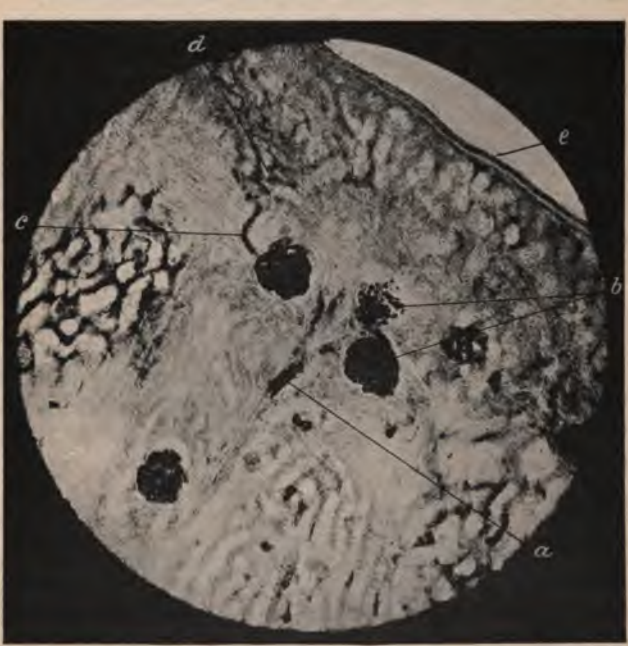

Fig. 54.—Section of kidney, blood-vessels injected: *a*, Small interlobular artery, sending branches as afferent arterioles to (*b*) several glomeruli; *c*, efferent arteriole, emerging from glomerulus to form (*d*) capillary network; *e*, capsule.

uriniferous tubules of the labyrinth and medullary ray, a few vessels reaching down into the Malpighian pyramids.

The capillaries join to form small veins (the **interlobular veins**), which empty into the *venous arcades*, and thence into the *interpyramidal veins* and into the *renal vein*, running parallel to the arteries of similar names. Just beneath the capsule some of the vessels form small, irregular sinuses, called the **venæ stellæ.**

The **arteriæ rectæ** form capillaries, which run between and encircle the uriniferous tubules in the Malpighian pyramids, form a network around the openings of the capillary tubules, and return by the *venæ rectæ* (by the side of the arteriæ rectæ) to empty into the venous arcade previously described.

LYMPHATICS.

The **lymphatics of the kidney** are not well defined. One system is found in the capsule, the other in the basement membrane and fibrous tissue between the tubules.

NERVES.

The **nerves of the kidney** are of the nonmedullated variety. They enter at the hilum with the blood-vessels, follow the course of the latter, and send small branches between and around the uriniferous tubules. But little is known of their ultimate termination.

THE SINUSES, PELVIS, AND URETERS.

The **sinus, pelvis,** and **ureters** are covered by three layers of tissue—a *fibrous*, a *muscular*, and an *epithelial*, The **fibrous coat** is an extension of the capsule, lies in contact with the kidney-substance proper, and continues as the outer coat of the ureters, at the distal end of which its fibers merge into the outer surface of the bladder.

The **muscular coat** in the sinus and pelvis consists of two coats—an *outer* (next the fibrous coat) *longitudinal*, and an *inner circular*. Over the papillæ the longitudinal fibers disappear. In the ureter the same layers persist, with the addition, near the bladder, of a third more internal coat, in which the fibers run longitudinally.

The **epithelial coat** is continuous with the lining of the papillary ducts, immediately becoming of the *transitional* variety at the orifices of those structures, and extending to the epithelial lining of the bladder. A slight *basement membrane* underlies the epithelial coat and separates it from the muscular.

A few blood-vessels and nerves are found, mostly in the outer fibrous coat.

THE URINARY BLADDER.

The **bladder** has a fibrous, a muscular, and an epithelial coat, continuous with those of the ureters. At the areas covered by the peritoneum a fourth or serous coat will be found.

The **fibrous coat** is rather thin, and contains numerous fibers of yellow elastic tissue.

The **muscular coat** composes the larger part of the bladder-wall, and contains three poorly defined layers of smooth muscle-fibers: viz., an *outer longitudinal*, a *middle circular*, and an *inner longitudinal*.

The **epithelial coat** is of the transitional type, and is thrown into folds when the bladder is empty and contracted, the cells then being thicker and more nearly spheric. When distended, the cells become more elongated and flattened.

All the coats are richly supplied with *capillary blood-vessels.*

Lymphatics are also abundant, especially so just beneath the epithelial surface, in which locality *lymph-follicles* also occur. Both *medullated* and *nonmedullated nerve-fibers* as well as small *ganglia* may be observed in moderate numbers.

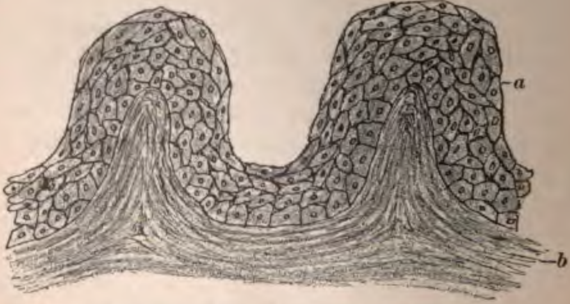

Fig. 55.—Urinary bladder mucous membrane: *a*, Epithelium of the transitional type; *b*, muscular coat.

THE URETHRA.

The **male urethra** has three layers, from within outward—a *mucous*, a *muscular*, and a *fibrous* may be distinguished.

The **mucous coat** has an epithelial surface, varying in different localities and resting upon a fibro-elastic tunica propria, or basement membrane. The **epithelium** is transitional, and is continuous with that of the bladder in the prostatic portion. In the membranous portion it is columnar and stratified; in the spongy or penile portion it is but a single layer in thickness, and is columnar. In the fossa navicularis it is continuous with the external covering of the glans penis, and is of the stratified squamous variety. Small racemose glands (the *glands of Littre*) occur throughout the length of the mucous coat.

The **muscular coat** is of smooth muscle, arranged as an *inner longitudinal* and an *outer circular layer* in the prostatic and membranous portions of the urethra, but disappearing in the penile portion.

The **fibrous coat** surrounds the muscular; when present in the penile portion, it supports the mucous membrane.

The **female urethra** has the same three coats as the male: viz., mucous, muscular, and fibrous.

The inner surface, especially near the meatus, is covered with irregular projections—the *papillæ*. The **mucous coat** is lined throughout with *stratified squamous epithelium*. The *tunica propria* is similar to that in the male, but the small glands are much fewer in number. The fibers of the **muscular coat** are also arranged in an *inner longitudinal* and an *outer circular layer*. The *mucous coat* is richly supplied with *capillaries*. *Lymphatics* and *nerves* occur in abundance beneath the mucosa, the latter terminating just below the epithelium.

QUESTIONS FOR CHAPTER IX.

190. Describe the gross appearance of the kidney.

191. What is the capsule? cortical portion? medullary portion? What are the pyramids of Malpighi? the papillæ?

192. What are the columns of Bertini?

193. What are the medullary rays or pyramids of Ferrein?

194. What is the labyrinth?

195. What is the hilum? pelvis? sinus? What are the infundibula, or calyces?

196. What is a uriniferous tubule?

197. Outline general course of a tubule; give names of each location.

198. Describe a Malpighian body.

199. What is the capsule of Bowman?

200. Give the structure of a uriniferous tubule.

201. Give relative sizes of tubules in different locations.

202. How does the size of the lumen compare with the size of the cells surrounding it?

203. Describe the blood-supply of the kidney.

204. What is the arterial arcade?

205. What are the arteriæ rectæ?

206. What are the venæ stellæ?

207. Describe the lymphatics of the kidney; nerve-supply.

208. What is the structure of the sinus, pelvis, and ureters?

209. Describe their fibrous coat; muscular coat; epithelial coat.

210. Of what coats is the urinary bladder composed?

211. Describe its fibrous coat; muscular coat; epithelial coat.

212. What are the layers composing the urethra?

213. Describe the mucous coat; muscular coat; fibrous coat.

214. Describe the female urethra.

CHAPTER X.

THE MALE GENERATIVE ORGANS.

THE TESTICLE.

THE **testicle** is a compound arrangement of coiled tubular glands. It is covered externally by a capsule of fibrous elastic tissue, the **tunica albuginea,** which at the posterior portion becomes very much enlarged, in which location it is called the **mediastinum,** or **body of Highmore.**

The tunica albuginea is further divided into two layers: the outer, covering most of the organ, being an extension of the peritoneum, has the structure of a serous membrane, and is called the **tunica vaginalis**; the inner contains a rich blood-supply, and is called the **tunica vasculosum.**

The mediastinum and the tunica vasculosum are connected by septa of fibrous tissue, which divide the body of the organ into irregularly pyramidal *lobules.*

In these lobules lie a varying number of the *seminiferous tubules* (from 300 to 800), which begin as closed tubes near the periphery of the lobule and run to the edge of the mediastinum, where they unite into from 20 to 30 larger ducts (the **vasa recta**) and enter the mediastinum, anastomosing with one another to form a mass, called the **rete testis,** whence they emerge from the upper edge of the mediastinum as a dozen or so tubules (the **vasa efferentia**). These pass through the tunica albuginea, and at first follow a straight course; then form a series of conic masses (one for each tubule), called the **coni vasculosi,** the entire mass constituting the **globus major** of the epididymis. At the bottom of the globus major all the tubules open into a larger single tube (the **body of the epididymis**), which runs a very convoluted course, dilating at its end to form the **globus minor,** which empties into the **vas deferens.** This follows the spermatic cord through the internal abdominal ring and passes to the base of the bladder, where it joins the duct of the **vesicula seminalis** to form the **ejaculatory duct,** which passes through the prostate to the verumontanum of the urethra.

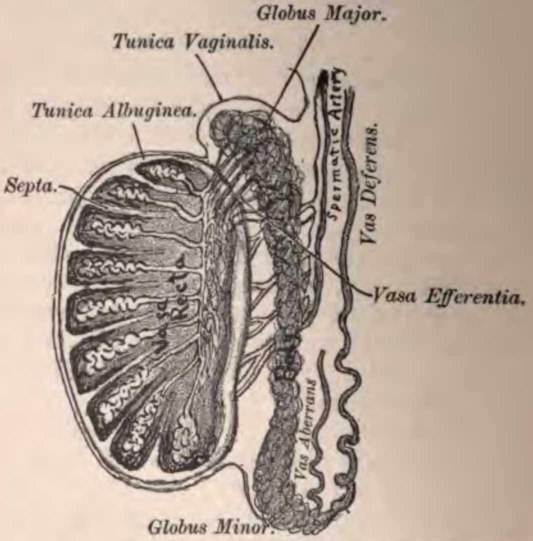

Fig. 56.—Vertical section of the testicle to show the arrangement of the duct.

The *seminiferous tubules* may be divided into three portions:

1. The *convoluted tubules,* occupying about the outer three-fourths of the lobules.
2. The *straight tubules,* which continue to the vasa recta.
3. The *tubules in the mediastinum.*

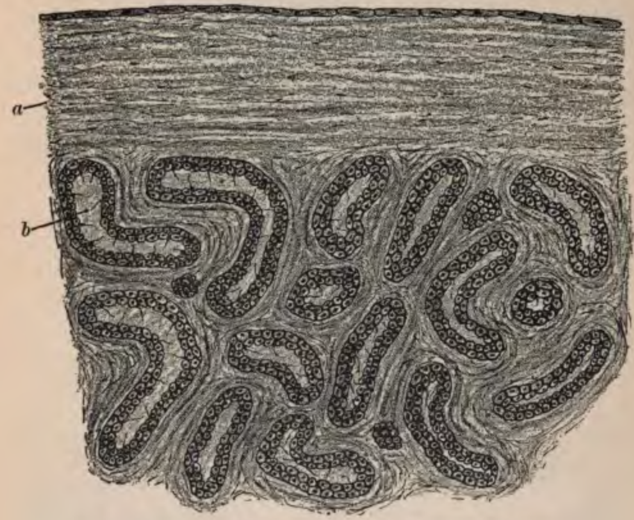

Fig. 57.—Testicle: *a,* Tunica albuginea; *b,* seminal tubule.

In structure the seminiferous tubules consist of an outer covering of *flat endothelial cells,* which surround a thin *basement membrane.* Internal to this are several layers of irregular *epithelial cells,* more or less of which will be found to be in process of karyokinesis according to the functional activity of the organ.

The *outer* epithelial cells are called the **parietal**

cells, and are of two kinds: the first, or **sustentacular cells,** or **Sartoli's columns,** take no active part in the production of the spermatozoa; the second, or **spermatogenic cells,** are the eventual progenitors of the spermatozoa. Inside of the parietal cells a second layer may be distinguished, many of which in the active organ will be found to exhibit mitotic figures. These cells are the direct descendants of the spermatogenic cells, and are called the *mother cells.* The mother cells by their multiplication give rise to a third layer of cells, internal to the previous two, called the *daughter cells.* These cells are somewhat smaller than the mother cells, and at the inner portion of the layer many of their nuclei may be seen from around which

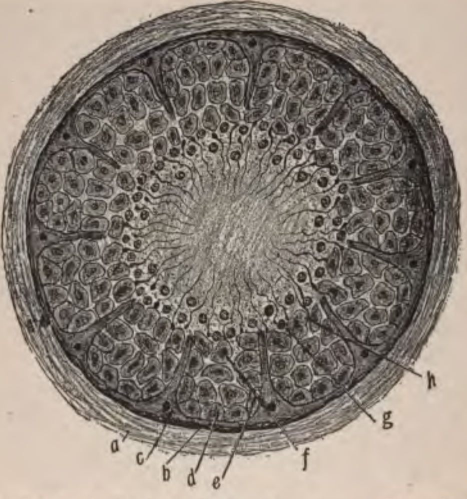

Fig. 58.—Tubule of testicle: *a*, Fibrous tissue surrounding tubule; *b*, basement membrane; *c*, sustentacular cells; *d*, spermatogenic cells; *e*, mother cells in the process of mitosis; *f*, daughter cells; *g*, spermatoblasts; *h*, spermatozoa.

most of the cell-body has disappeared, forming the **spermatoblasts.** From the spermatoblasts the **spermatozoa** are formed, and may be seen with their heads embedded among the spermatoblasts and the daughter cells.

The **spermatozoa** in man are about 50 microns in length, and consist of a *head*, a *body* or *middle piece*, and a *tail.*

The *head* is flattened ovoid in shape, its under surface being slightly concave. It measures about one-twelfth of the entire length of the spermatozoa, or 3 or 4 microns.

The *body* is attached to the posterior part of the head, where it is about 1 micron wide and tapers down for a distance of from 4 to 6 microns, where it joins the tail as an extremely delicate filament.

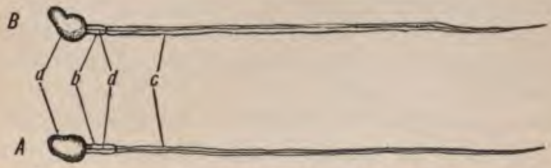

Fig. 59.—Spermatozoa: *A*, Flat view; *B*, side view; *a*, head; *b*, body; *c*, tail; *d*, axial fiber.

The *tail* forms the greatest part of the total length, measuring about 40 microns. It is a very thin, hair-like filament, which, when the spermatozoa is alive, has a very rapid lashing movement, by virtue of which the element is enabled to travel at a considerable rate of speed in fluids. Running through the center of the body and tail is a fine line, called the *axial fiber*, which at the end of the tail is uncovered and forms the termination of that part. The spermatozoa possess much vitality, being able under favorable circumstances to retain their power of movement for several days outside the body.

The *seminiferous tubules* are held together by loose connective tissue, embedded in which at irregular intervals small masses of polyhedral epithelial cells occur, termed the *interstitial cells.* These are the remains of a fetal structure—the **Wolffian body.**

The *straight tubules* are smaller than the convoluted tubules, measuring only about 25 microns in diameter. They are lined with a single layer of short columnar epithelium, the external coat remaining the same.

The **tubules of the rete testis** vary much in size, and are lined by a single layer of flat epithelium.

The **vasa efferentia** and the **coni vasculosi** are lined by several layers of *columnar epithelium,* the innermost layer of which is provided with long *cilia.* The fibrous coat contains many fibers of smooth muscle, arranged circularly.

The **epididymis** is similar to the vas efferentia in structure, but the smooth muscle-fibers increase in number and size.

The **vas deferens,** or **spermatic duct,** has, in addition to the structure of the epididymis, a well-marked, smooth, muscular coat, the inner layer of which runs circularly, the outer layer longitudinally.

The **vesicula seminalis** continues the structure of the vas, but contains in its mucosa numerous small tubular glands.

The **ejaculatory duct** differs from the vesicula seminalis in being lined by a single layer of columnar epithelium.

The *blood supply* of the testicles enters the tunica vasculosa and mediastinum, whence it is distributed through the septa, and thence by small branches to the intertubular connective tissue, there breaking up into capillaries surrounding the tubules and returning through veins accompanying the arteries.

Two sets of *lymphatics* are present: the first, within the tunica albuginea; the second, or deep, surrounds the seminiferous tubules and rete testis, emptying into the large lymphatic vessels of the spermatic cord, which in turn terminate in the lumbar glands.

Both *medullated* and *nonmedullated nerve-fibers* are found between the seminiferous tubules.

THE SEMEN.

The **semen** contains, besides the spermatozoa, numerous *epithelial cells; round, albuminous granules; clear, waxy, cylindric masses* from the vesicula seminalis; and some spheric or irregular yellowish bodies, which contain concentric markings suggestive of those found in the potato starch. These bodies are called the **prostatic concretions,** or **amyloid bodies.**

THE PENIS.

The body of the **penis** is covered externally by skin with its stratified epithelium, the subcutaneous tissue of which contains little or no fat. It is free from hairs, and at the juncture of the prepuce and glans numerous small tubular glands (the **glands of Tyson,** or **glandulæ odoriferæ**) occur, which secrete the smegma. The glans penis is covered with a stratified mucous membrane having but little submucosa and being firmly adherent to the underlying corpus spongiosum. The under surface of the mucosa is indented by large papillæ, in which the *genital corpuscles* are situated.

Beneath the subcutaneous tissue in the dorsal portion of the organ is found a thick oval sheath of longitudinal fibrous tissue, interspersed with much yellow elastic tissue (the **tunica albuginea**), surrounding two masses of erectile tissue (the **corpora cavernosa**), each of which is also covered with an individual circular coat of fibro-elastic tissue. Below the corpora cavernosa is another body of erectile tissue, surrounded by a less distinct sheath, called the **corpus spongiosum**, in the center of which is situated the **urethra.**

The **corpora cavernosa** are composed of very numerous branching irregular *trabeculæ*, which extend from the surrounding fibro-elastic sheath, and contain scattered groups of smooth muscle-fibers. The spaces formed between the trabeculæ are lined with endothelium, and, being connected with the arteries and veins, form large sinuses, which become enormously distended during erection.

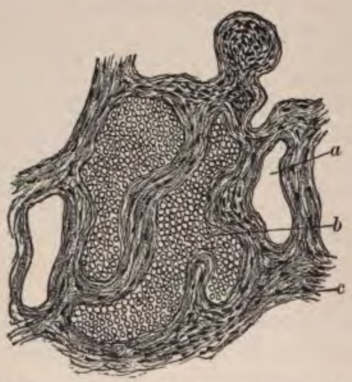

Fig. 60.—Section of erectile tissue: *a*, Blood spaces; *b*, blood-corpuscles; *c*, walls composed of fibrous tissue and smooth muscle.

The **corpus spongiosum** contains much the same structure as the corpora cavernosa, the trabeculæ, however, being much finer and the blood spaces smaller and more regular in size. At the glans it expands, covering the ends of the corpora cavernosa, and is covered directly by the mucosa of the glans.

The **male urethra** lies in the center of the corpus spongiosum, and extends from the bladder to the meatus.

The *blood supply* is derived from the dorsal arteries and the arteries of the corpora cavernosa, which break up into capillaries, most of which empty into the blood spaces of the corpus spongiosum and corpora cavernosa, thence to be drained by the small veins emptying into the dorsal vein or to pass out at the root of the organ into the prostatic venous plexus.

Some of the arteries entering the corpora cavernosa do not at once break up into capillaries, but form tortuous vessels, which in the nonerect condition of the organ form loops, which project into the cavernous spaces. These have been called the **helicene arteries.**

Many of the capillaries from these arteries supply the tissue of the trabeculæ and return through the veins without emptying into the cavernous spaces. A deep and a superficial set of *lymphatics* are present; the latter being distributed in the subcutaneous tissue and accompanying the superficial vessels, and terminating in the inguinal glands; the former arising in the corpus spongiosum and corpora cavernosum, following the deep blood-vessels, to terminate in the deep lymphatics of the pelvis.

The *nerves* are both medullated and nonmedullated, from the pudic and hypogastric plexus of the sympathetic.

Both the *Pacinian bodies* and *genital corpuscles* are found.

THE PROSTATE.

The **prostate** is a compound tubular gland, and is inclosed by a two-layered capsule, the outer layer of which is fibrous tissue, the inner layer, smooth muscle.

From the muscular layer the main stroma of the gland is derived, containing but occasional fibrous tissue bundles. The acini of the gland are lined with a single layer of columnar epithelium. Frequently, between this epithelium and its basement membrane numerous small, roundish cells are found. Occasionally, especially in old age, the acini will be found to contain clearish, rounded, laminated masses, of an albuminous nature, called the **prostatic concretions.**

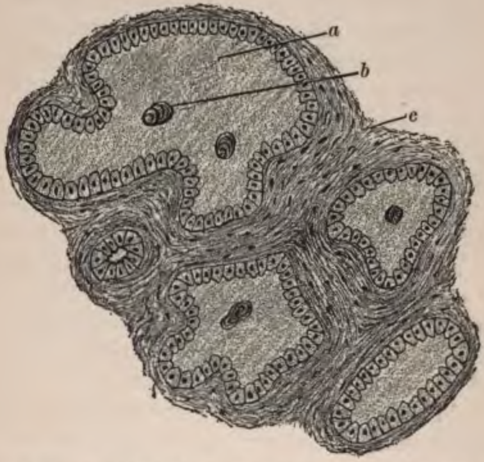

Fig. 61.—Prostate: *a*, Acini; *b*, prostatic concretion; *c*, intertubular smooth muscle.

The larger ducts are lined with a stratified epithelium, continuous with that of the urethra. The *blood supply* enters the capsule and is distributed in a rich capillary network about the acini and within the fibrous capsule.

Lymphatic clefts occur in the fibrous septa and accompany the veins.

Medullated and nonmedullated *nerve-fibers* occur between the acini, but their mode of termination is unknown. **Corpuscles of Vater** are also occasionally found.

COWPER'S GLANDS.

Cowper's glands are two small, compound, saccular or racemose glands lying beneath the membranous urethra. The acini are lined by a single layer of short columnar cells.

QUESTIONS FOR CHAPTER X.

215. What type of gland is the testicle?

216. What is the tunica albuginea?

217. What is the mediastinum?

218. Into what is the tunica albuginea divided?

219. Describe the lobules.

220. Describe the course of the seminiferous tubules from their beginning to the ejaculatory duct.

221. What are the three portions of the seminiferous tubules proper?

222. Describe the structure of a seminiferous tubule.

223. What are the sustentacular cells?

224. What are the spermatogenetic cells? mother cells? daughter cells? spermatoblasts?

225. Describe the spermatozoa.

226. What are the interstitial cells of the testicle?

227. Describe the vasa rectis; the vasa efferentia; the epididymis; the vas deferens.

228. Describe the vesiculæ seminalis and the ejaculatory duct.

229. Give the course of the blood-vessels in the testicle; of the lymphatics; of the nerves.

230. Describe the penis.

231. Give the general structures composing the penis.

232. What are the glands of Tyson?

233. What is the character of the covering of the penis? of the glans?

234. What is the tunica albuginea?

235. What are the corpora cavernosa? What is the corpus spongiosum?

236. Describe the structure of each.

237. Give the blood distribution of the penis. What are the helicene arteries?

238. Describe the lymphatics and nerves of the penis.

239. What type of gland is the prostate?

240. Describe its general arrangement.

241. What are the prostatic concretions?

242. Give the blood supply; the lymphatic and nerve supply.

243. Describe Cowper's glands.

CHAPTER XI.

THE FEMALE GENERATIVE ORGANS.

THE OVARY.

THE **ovaries** are small almond-shaped masses attached to the posterior surface of the broad ligament. They are covered by two layers of tissue. The first is a modified reflection of the peritoneum, containing a single layer of columnar epithelial cells, called the **germinal epithelium.** The second layer is composed of fibrous tissue, and is called the **tunica albuginea.** In the germinal epithelium, more especially in the fetus, occasional large, clear, ovoid cells containing a prominent nucleolus are found. These are the **primordial ova,** and are the cells from which the ova are developed.

The substance of the ovary is divided into a **cortical** and a **medullary portion,** which merge imperceptibly into one another.

Beneath the tunica albuginea is the **ovarian stroma,** which consists of a peculiar fibrous tissue containing many long **spindle-shaped cells** arranged irregularly.

Embedded in the stroma of the cortex lie a large number (36,000) of **Graafian follicles.** These differ in size and appearance according to their stage of development.

The *immature follicles* are produced by a downgrowth of the germinal epithelium surrounding one of the primordial ova. This downgrowth is cut off from the surface by the growing-in of the stroma and leaving the ovum surrounded by a granular layer of cells of greater or less thickness according to the stage of development. These in turn are surrounded by a slightly denser concentric arrangement of the spindle-shaped cells of the stroma.

The *mature Graafian follicles* are much larger in size, measuring from 4 to 8 mm. in diameter.

They are bounded externally by a denser layer of the stroma, called **theca folliculi**, in which two layers may be distinguished. The outer layer, or **tunica externa**, is more fibrous and contains the larger blood-vessels. The inner coat, or **tunica interna**, is more cellular in character and contains smaller blood-vessels and capil*laries*.

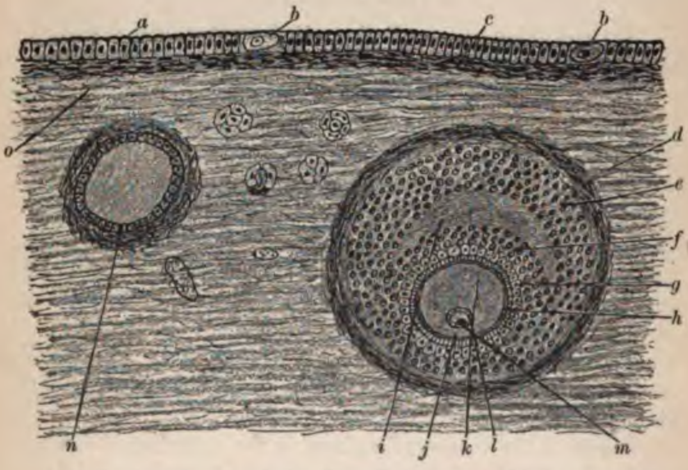

Fig. 62.—Ovary: *a*, Germinal epithelium; *b*, primordial ova; *c*, tunica albuginea; *d*, theca folliculi; *e*, stratum granulosum; *f*, discus proligerus; *g*, corona radiata; *h*, zona pellucida; *i*, cavity of liquor folliculi; *j*, vitelline membrane; *k*, vitellus; *l*, germinal vesicle; *m*, germinal spot; *n*, immature follicle; *o*, stroma.

Inside of the **theca folliculi** is a granular layer of cells derived originally from the germinal epithelium, and called **stratum granulosum.**

At some point the cells of the stratum granulosum are heaped up, forming a mass called the **discus proligerus,** or **cumulus ovigerus,** the inner layer of which is arranged radially, and called the **corona radiata,** which in turn surrounds a delicate radially striated membrane, the **zona pellucida.**

The centers of the follicles contain a cavity bounded by the stratum granulosa and containing a clear fluid, called the **liquor folliculi.**

The **ovum** lies within the zona pellucida, and is bounded by a thin, transparent membrane, called the **vitelline membrane.** Within this is a granular mass, called the **vitellus.** Situated excentrically in the vitellus is the **germinal vesicle,** which is bounded externally by a delicate wall, contains many chromatin fibers, and a small body, resembling a nucleolus, called the **germinal spot.**

Graafian follicles of all degrees of development between the immature and fully matured may be found.

When a follicle is ripe, the liquor folliculi distends it until it ruptures at the surface of the ovary and the ovum is discharged with a portion of the discus proligerus adherent.

The wounds in the surface thus formed are healed up by a multiplication of the cells of the stratum granulosum, forming large polyhedral cells, between which fibers from the stroma carrying capillaries penetrate. The mass thereby produced is yellowish in color, and is called the **corpus luteum.** This varies in size and development accordingly as pregnancy has taken place or not. If pregnancy has occurred, the mass is called a **true corpus luteum**; if not, the development will be much less, and a **false corpus luteum** results.

The **blood-supply** of the ovary enters at its attachment to the broad ligament and proceeds to the medulla, whence branches are given off to the stroma, forming a capillary network in the theca folliculi.

The **lymphatics** are most numerous in the medulla, but also occur in the cortex and theca folliculi.

Both medullated and nonmedullated nerve-fibers occur, first penetrating to the medulla, from which fine branches are distributed to the cortex and follicles.

THE PAROVARIUM.

The **parovarium, epoöphoron,** or **organ of Rosenmüller,** as it is variously termed, is the remains of a fetal structure called the **Wolffian duct.** It is situated in the broad ligament, between the ovary and the Fallopian tube. In structure it is found to contain a number of small converging tubes leading to a larger transverse tube, all of which are lined by short columnar epithelial cells, some of which are found in the lumina of the tubules.

THE FALLOPIAN TUBES.

The **Fallopian tubes,** or **oviducts,** have three coats—an outer *fibroserous,* a middle *muscular,* and an inner *mucous.*

The outer or **fibroserous** consists of a reflection of the peritoneum, being covered externally by a layer of flat endothelium, supported by a layer of fibrous tissue containing many fibers of smooth muscle.

The **muscular coat** has two layers—an outer longitudinal and an inner circular, the latter being much the larger.

The **mucous coat** has a well-developed **membrana propria**, which is very much plicated, giving a transverse section of the lumen a very irregular outline. This is lined by a single layer of ciliated columnar epithelium.

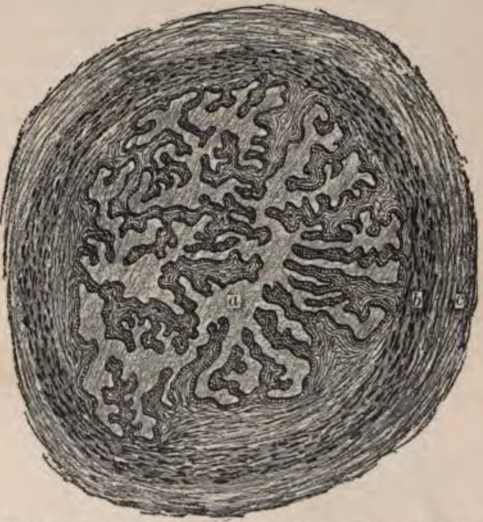

Fig. 63.—Fallopian tube: *a*, Tortuous lumen; *b*, muscular coat; *c*, fibrous coat.

THE UTERUS.

The **uterus** also contains three coats—an outer *serous*, a middle *muscular*, and an inner *epithelial*.

The **serous coat** consists of a layer of peritoneum, being covered by a layer of endothelial cells which rests upon a layer of fibrous tissue.

The **muscular coat** constitutes the bulk of the organ, and may, with difficulty, be divided into three layers of smooth fibers, the outer layer of which runs mostly longitudinally, the middle layer mostly circularly, and the inner layer obliquely longitudinally.

In all the coats, however, many fibers are found at all angles to the general trend.

The **epithelial coat** contains a single layer of ciliated columnar epithelial cells, which rests upon a thin basement membrane, a true submucosa being absent.

Scattered throughout the epithelial coat are the mouths of wavy, branched tubular glands, the *uterine glands*, which are lined by a single layer of ciliated cells resting on a slight basement membrane. These glands, owing to the absence of the submucosa, extend to the muscular coat.

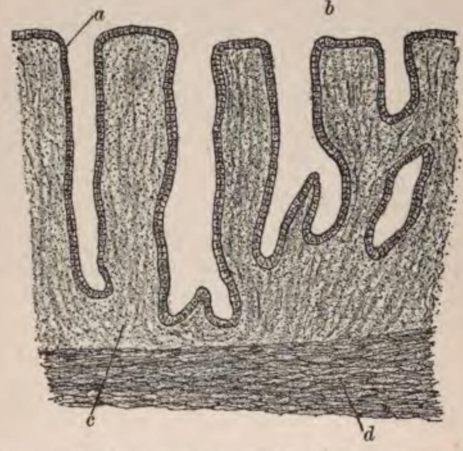

Fig. 64.—Uterus: *a*, Epithelial surface; *b*, uterine glands; *c*, intertubular fibrous tissue and cells; *d*, smooth muscular coat.

The lower half of the cervix is lined with **stratified squamous epithelium**, which is thrown into longitudinal folds, and in cross-section resembles papillæ. Here, also, short **mucous crypts** occur, which occasionally become occluded and form retention cysts, called the **ovulæ Nabothi.**

The **blood-vessels** penetrate the serous coat to the muscular, where they branch, sending some of their branches to the internal coat, there encircling the uterine glands and epithelium in a network of capillaries. In the middle coat large thin-walled **blood-spaces** occur between the fasciculi of muscular tissue.

The **lymphatics** form a network beneath the epithelial coat, unite with slightly larger vessels in the muscular coat, and empty into the large vessels of the serous coat.

Medullated and nonmedullated *nerve-fibers* occur in the muscular coat, sending fine branches to the epithelial surface. Along the course of the nonmedullated fibers small ganglia sometimes occur.

THE VAGINA.

The **vagina** has three coats—external *fibrous,* middle *muscular*, and inner *mucous.*

The **fibrous coat** is well developed, and contains many fibers of yellow elastic tissue scattered through the main bulk of white fibers.

The **muscular coat** consists of an *outer longitudinal* and an *inner circular layer* of smooth muscle, the boundaries of which are ill defined.

The **mucous coat** consists of a well-developed membrana propria, studded with leukocytes, which is thrown into frequent ridges (the *rugæ*) and projections (*papillæ*). This is covered by a deep layer of *stratified epithelium* the outer layers of which are squamous.

The **blood-vessels** run near the outer surface of the membrana propria, from which situation smaller branches are sent into the muscular tissue and to the under surface of the epithelium.

Between the muscular and mucous coats the veins are arranged in a complex network, giving to the part slight erectile properties.

The **lymphatics** in the mucosa empty into those of the muscular coat, and these in turn communicate with those of the fibrous coat.

Medullated and nonmedullated **nerve-fibers, ganglia** and **special nerve-endings** (the **genital end-bulbs,** or the **genital corpuscles of Krause**) occur in the mucosa.

The **labia majora** are covered with stratified epithelium, the deep layers of which are more or less pigmented. Hair follicles, sweat-glands, and sebaceous follicles are numerous. Beneath the epithelium is a loose areolar tissue containing much fat and some muscular and elastic fibers.

The **labia minora** are covered with stratified epithelium, which contains neither fat, hair follicles, nor sweat-glands. The subepithelial tissue is loose in texture and contains many large blood-spaces, making the tissue moderately erectile.

Medullated and nonmedullated **nerves** and **genital corpuscles** occur.

The **clitoris** consists of two masses of erectile tissue (the corpora cavernosa) inclosed in a sheath of fibrous tissue and covered externally by stratified epithelium. **Genital corpuscles** are numerous.

The **glands of Bartholin** are small *racemose glands* lying at either side of the beginning of the vagina. They are lined with clear mucous cells, which discharge their secretions through a tube lined with short columnar epithelium.

THE MAMMARY GLANDS.

The **mammary glands** are complex tubular glands, the several lobes of which are held together by fibrous tissue and fat, and empty side by side through the nipple. The **acini** are lined by a single layer of granular, polyhedral epithelial cells, which rests upon a distinct membrana propria. As in other glands, the acini are grouped into lobules and then into lobes, all of which are surrounded by a greater or less amount of fibrous tissue according to their size.

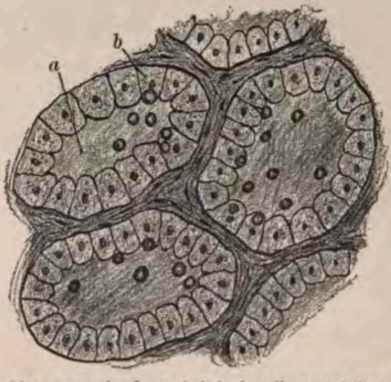

Fig. 65.—Mammary gland: *a*, Acini; *b*, cells containing globules.

During lactation the epithelial cells are seen to contain numerous droplets of oil in their substance. More or less oil will also be found in the acini.

The **blood-vessels** run between the lobules and send branches into the fibrous tissue, which break up into capillary network surrounding the acini.

The gland is well supplied with **lymphatics**, which occur both in the subcutaneous tissue and in the interacinous fibrous tissue and communicate with the glands of the axilla.

The **milk** consists of a clear fluid, suspended in which are immense numbers of oil droplets, together with some granular matter from the cells lining the acini and tubules.

During the first few days of lactation certain large, granular, fatty, highly refracting bodies occur, which have received the name of **colostrum corpuscles.**

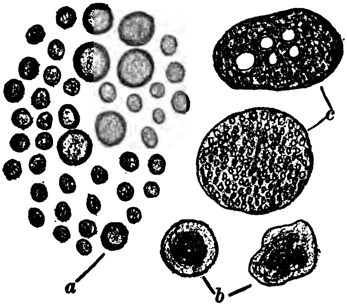

Fig. 66.—Elements of milk: *a*, Droplets of oil in milk; *b*, leukocytes; *c*, large colostrum corpuscles.

QUESTIONS FOR CHAPTER XI.

244. Describe the general characteristics of the ovary.
245. What is the germinal epithelium? the primordial ova?
246. What is the tunica albuginea?
247. What is the ovarian stroma?
248. What are the Graafian follicles? Where do they originate?
249. Give the structure of the mature Graafian follicle.
250. Describe a corpus luteum.
251. Describe the ovum.
252. Name the layers of the Graafian follicle and ovum in their sequence.

253. Describe the blood-supply of the ovum; the lymphatic; the nerve.

254. Describe the parovarium.

255. Describe the Fallopian tube; give its structure.

256. Name the coats of the uterus. Describe each.

257. Describe the uterine glands.

258. Describe the cervix.

259. What are the ovulæ Nabothi?

260. Describe the blood distribution of the uterus; the lymphatics; the nerves.

261. Name the coats of the vagina. Describe each.

262. Give the blood-, lymph-, and nerve-supply.

263. Describe the labia majora, the labia minora, and the clitoris.

264. What are the glands of Bartholin?

265. What type of glands are the mammary glands?

266. Describe them.

267. Give their blood- and lymphatic supply.

268. Describe the milk.

269. What are colostrum corpuscles?

CHAPTER XII.

THE RESPIRATORY SYSTEM.

THE **larynx** is lined with stratified ciliated epithelium, resting on a thin membrana propria of fibro-elastic tissue. Beneath this is the **submucosa** of fibrous tissue, which contains numerous branched tubular glands communicating with the surface. In the external portion of the submucosa are the cartilages of the larynx. Those of the thyroid, cricoid, and arytenoid are of the hyaline variety, the epiglottis and the cartilages of Wrisberg and Santorini being of the yellow, elastic variety.

The **trachea** is lined with stratified ciliated columnar epithelium resting upon a tunica propria. Numerous small racemose glands dip down from the surface into the submucosa below. The **submucosa** is surrounded by the fibrous coat, embedded in which are a number of **C-shaped plates** of **hyaline cartilage**, which surround the trachea on all sides except at its juncture with the esophagus, and which serve to keep the tubes open. External to the cartilage is a slight layer of circular, smooth muscle.

The **larger bronchi** continue the structure of the trachea, dividing repeatedly until the smaller tubes are reached, when the cartilage rings become smaller and smaller, until they entirely disappear. The epithelium is reduced to a single layer and the muscular coat becomes relatively better developed.

THE LUNGS.

The smaller bronchi divide until the **terminal bronchi** are reached, the diameter of each of which is about 1 mm. ($\frac{1}{25}$ inch). These, again, branch to form narrow tubules, the **alveolar ducts**, which open into dilated pouches, called the **infundibula**, from which again a number of air-sacs or **alveoli** open.

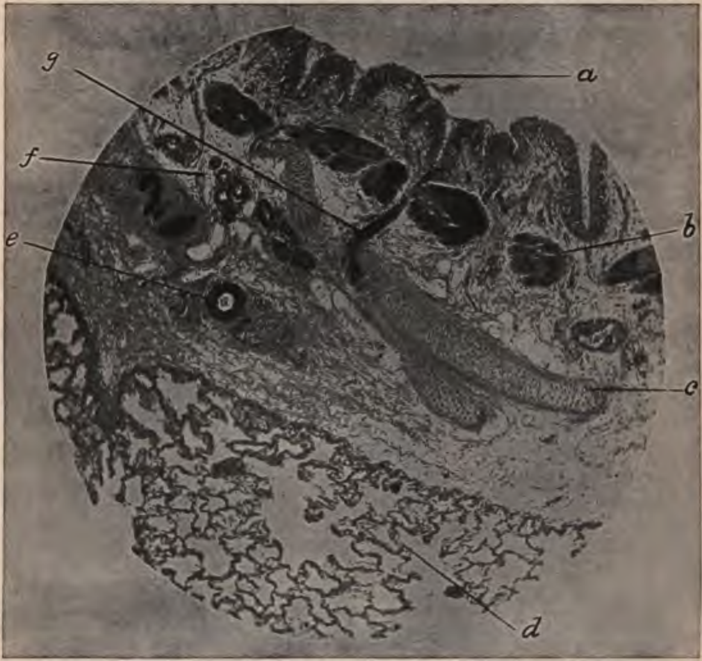

Fig. 67.—Bronchial tube: *a*, Mucous membrane; *b*, muscularis mucosæ; *c*, cartilage plate; *d*, lung tissue; *e*, small artery; *f*, bronchial gland; *g*, duct of bronchial gland.

The **alveolar ducts** are lined with nonciliated low columnar cells lying on thin, fibrous, elastic basement membrane.

The alveoli are lined with a single layer of epithelium.

The groups of acini belonging to a terminal bronchus are united to a number of similar groups by fibro-elastic tissue to form a **lobule.**

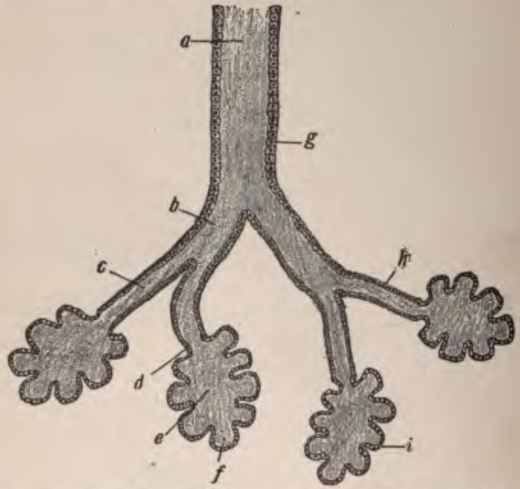

Fig. 68.—Diagram of bronchial terminations: *a*, Smaller bronchus; *b*, terminal bronchus; *c*, alveolar duct; *d*, constriction, or neck; *e*, space of infundibulum outlined by dotted lines; *f*, infundibula; *g*, ciliated columnar cells lining small bronchus; *h*, nonciliated columnar cells lining alveolar ducts; *i*, flat epithelium lining alveoli.

Numerous lobules are similarly united to form the **lobes,** the external surface of which are covered by a serous membrane, the **pleura.**

The **blood-vessels** follow the course of the bronchi, dividing into a capillary network in the alveolar walls to surround the alveoli with a very complete network. It is in these capillaries that the oxidation of the blood takes place, the gases having to traverse only the capillary wall, an extremely small amount of fibro-elastic tissue, and the thin epithelial lining of the alveoli. The veins return by the side of their respective arteries.

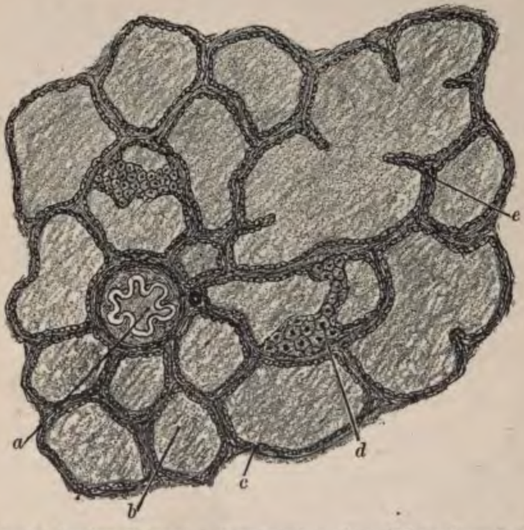

Fig. 69.—Section of lung: *a*, Cross-section of small bronchus; *b*, alveolus; *c*, alveolar wall lined with flat epithelium; *d*, top wall of alveolus entirely cut across; *e*, section into infundibulum, showing several alveoli opening into it.

Other small branches from the arteries occur which serve entirely to supply nutrition to the tissue.

The **lymphatics** form three systems: the first is found in the connective tissue beneath the **pleura** and communicates with the pleural cavity.

The second accompany the blood-vessels between the lobules.

The third begin under the epithelium of the bronchi, follow the blood-vessels to the root of the lung, where they unite with the previous two systems and pass into the **bronchial glands.**

Numerous masses of **diffuse adenoid tissue** occur in the submucosa of the trachea and bronchi, and small nodes occur especially near their bifurcations.

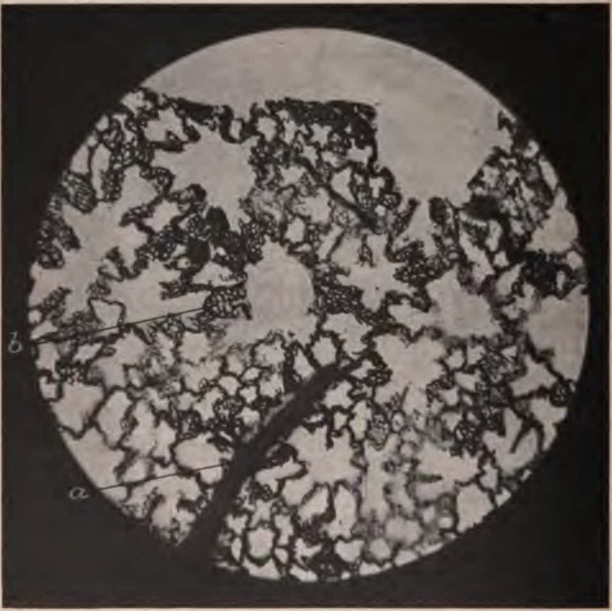

Fig. 70.—Section of lung in which the blood-vessels have been injected with carmin gelatin: *a*, Small artery, showing branches around alveoli and at (*b*) forming network over alveoli.

Both medullated and nonmedullated **nerve-fibers** are found following the course of the blood-vessels and lymphatic vessels. The termination of the fibers is unknown.

THE THYROID.

The **thyroid** is a compound tubular gland, the excretory ducts of which are closed. It falls within the classification of "ductless glands." It is surrounded by a **capsule** of fibrous tissue, which penetrates the body of the organ, dividing it into irregular lobules.

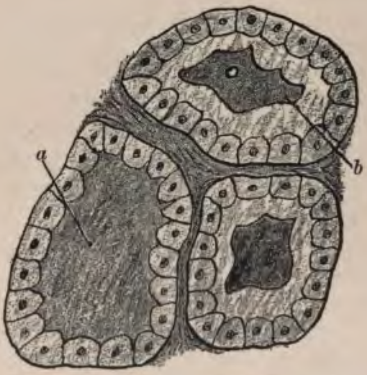

Fig. 71.—Thyroid gland: *a*, Acini completely filled with colloid material; *b*, same partly filled.

The acini are lined with short, columnar epithelium, resting upon a well-marked basement membrane. The lumen of the acini contain epithelial cells, leukocytes, granular matter, and occasional red blood-corpuscles, held together by a yellowish, gelatinous mass of colloid substance.

The **blood-vessels** enter the fibrous tissue between the lobules, and send rich capillary network to surround the acini.

The **lymphatics** are quite numerous, being found in the connective tissue of the capsule and between the lobules.

QUESTIONS FOR CHAPTER XII.

270. Describe the structure of the larynx.

271. Describe the structure of the trachea.

272. Describe the general structure of the air-passages.

273. What is the structure of the alveoli?

274. What structures separate the air from the blood in the alveolar capillaries?

275. Describe the blood-supply of the lungs, the lymphatics, and the nerve-supply.

276. What type of gland is the thyroid? Describe its structure.

277. What substance is found in its acini?

278. Describe its blood-vessels and lymphatics.

CHAPTER XIII.

THE CUTANEOUS SYSTEM.

THE **cutaneous system** embraces the skin, nails, hair, and glands. The teeth are also sometimes included, but have been described with the digestive system.

THE SKIN.

The **skin** consists of two distinct portions—the *cuticle*, *epidermis*, or *false skin*, and the *corium*, *cutis vera*, or *true skin*.

The **epidermis** is the more external of the two, and consists of several layers of epithelial cells, varying much in thickness in different locations.

The innermost layer of these cells (the **stratum Malpighii,** or **rete mucosum**) rests upon the irregularly projecting papillæ of the corium and consists of two or three layers of columnar cells. These cells are in rapid process of growth and multiplication, which is indicated by their darkly and easily staining. In the colored races, and in some situations in the white, these cells are found to contain pigment, to which the color of the skin is due.

External to these cells a layer of irregularly polyhedral cells connected with each other by minute spines is found, called the **prickle cells.** Outside of these a narrow layer of flattened polyhedral cells containing many granules of **eleidin** occur, called the **stratum granulosum.**

Above this is a narrow layer of still flatter polyhedral cells which are largely transformed into **keratin,** the nuclei showing very indistinctly (the **stratum lucidum**).

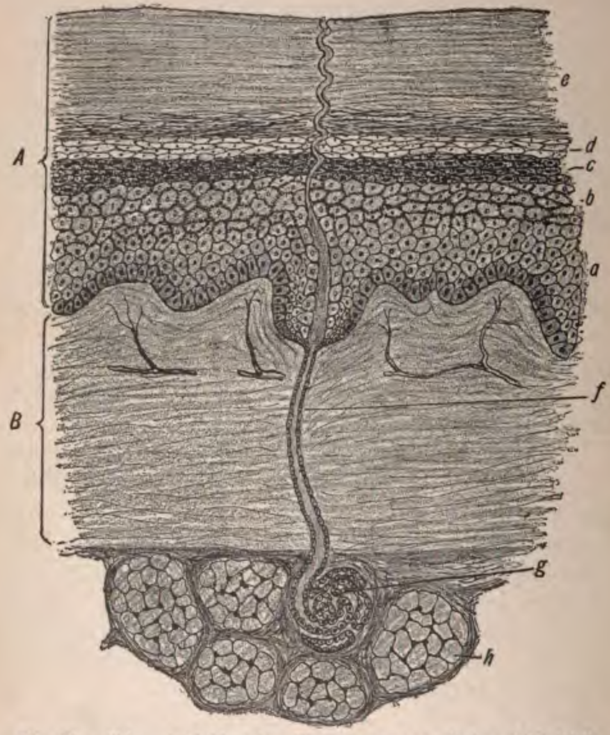

Fig. 72.—Skin: *A*, Epidermis; *B*, cutis vera; *a*, stratum Malpighii; *b*, prickle cells; *c*, stratum granulosum; *d*, stratum lucidum; *e*, stratum corneum; *f*, duct of sweat-gland; *g*, coil of sweat-gland; *h*, adipose tissue.

External to this and more superficial is the **stratum corneum,** consisting of squamous plates of hardened keratinized epithelial cells, which have entirely lost the appearance of ever having been nucleated.

The **corium** consists of two layers of fibro-elastic tissue; the external, a **stratum papillæ,** is quite dense and at its upper surface projects into the epidermis as papillæ, the upper surface of which contains the tactile nerve-organs. The internal layer, or **stratum reticulare,** is much looser in texture and merges gradually into the underlying tissues.

THE SEBACEOUS GLANDS.

The **sebaceous glands** are small racemose glands, situated in the corium, their excretory ducts discharging into the hair follicles, or from the free surface of the skin in localities where hair is absent.

The **acini** are lined by one or two layers of **cuboid epithelial cells,** the lumen being filled with a mass of degenerated cells, granular detritus, and a fatty, waxy secretion of the cells.

THE SWEAT-GLANDS.

The **sweat-glands,** or **sudoriferous glands,** are coiled, tubular glands which occur in great numbers (2,000,000) throughout the skin. The deeper portions of the glands lie in the stratum reticulare as a roundish, coiled mass, the excretory duct being straighter. The gland tubules consist of a single layer of pyramidal columnar cells resting upon a distinct basement membrane. In many of the glands, especially those of larger size, a more or less complete layer of smooth muscle exists between the cells and basement membrane.

The **excretory duct** is slightly smaller in size and lined with low cuboid cells up to the epidermis, where the course of the tubule becomes more spiral, its walls being formed by the epithelial cells until it terminates in a funnel-shaped expansion at the surface.

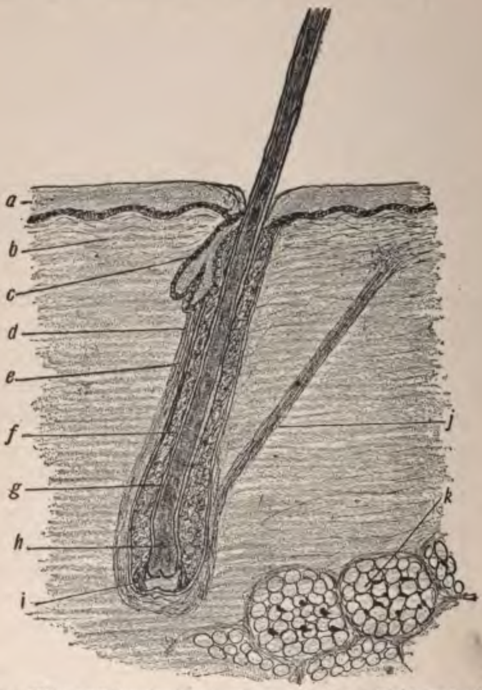

Fig. 73.—Skin and longitudinal section of hair: *a*, Epidermis; *b*, corium; *c*, sebaceous gland; *d*, fibrous root sheath; *e*, glassy membrane; *f*, outer root sheath; *g*, inner root sheath; *h*, expanded bulbous end of hair; *i*, papilla of hair; *j*, arrector pili; *k*, adipose tissue.

THE HAIR.

The **hair** is derived from the skin, and consists of two divisions—that within the skin called the *root*, and that external to the skin, the *shaft*.

The **root** lies embedded in a deep depression called the **hair follicle.**

The **shaft** consists of three layers—the *cuticle, cortical,* and *medulla,* all of which are composed of more or less modified epithelial cells.

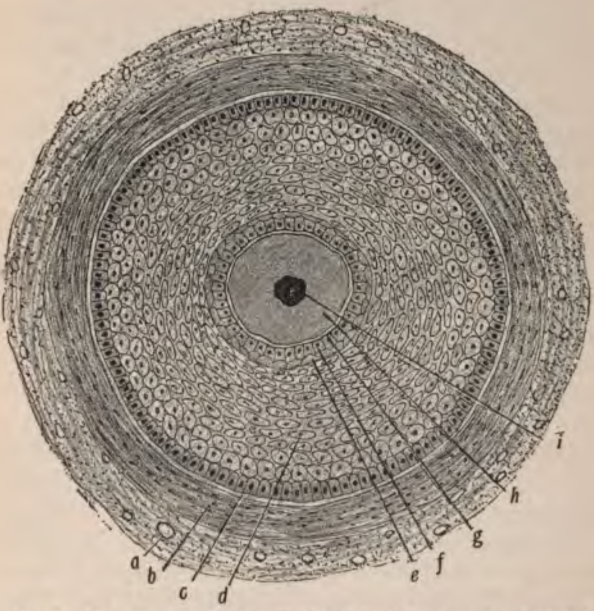

Fig. 74.—Cross-section of hair and follicle at level of root: *a*, Cut end of longitudinal fibers of sheath; *b*, circular fibers; *c*, glassy membrane; *d*, outer root sheath; *e, f*, Henle's and Huxley's layers of inner root sheath; *g*, hair cuticle; *h*, cortical portion of hair substance; *i*, medullary portion of hair substance (sometimes absent).

The **cuticle** is the outermost covering, and consists of a single layer of horny, nonnucleated cells which overlap one another like shingles.

The **cortical** or **middle layer** is the thickest, and is composed of many strata of greatly elongated, indistinctly nucleated, horny epithelial cells, which are very intimately united with one another.

These cells become broader and shorter in the root, where, not having become entirely altered, they resemble the cells of the stratum mucosum.

Scattered through the cortical portion is a greater or less amount of pigment upon which depends the color of the hair.

The **medulla** or **pith** is often absent, but when present, lies in the center of the hair fiber. It consists of two or three columns of cuboid cells which are usually filled with minute air-spaces, which give the medulla a silvery appearance when viewed by reflected light, but by transmitted light it appears black.

The **hair follicle** is a flask-shaped depression of the epidermis which extends down into the corium or subcutaneous tissue, according to the size of the hair, is surrounded by a fibrous sheath from the corium, and tightly encircles the hair root.

At the bottom of the follicle a small projection of the fibrous sheath (the hair papilla) extends a short distance into the hair bulb, carrying with it blood-vessels and pigment cells.

The **outermost coat** of the follicle is the **fibrous sheath,** which is derived from the corium, and consists of three layers—the outer *longitudinal,* the middle *circular,* the inner *glassy* or *hyaline layer,* a delicate structureless membrane upon which the epithelium of the middle coat rests.

The **middle coat** of the follicle is called the **outer root sheath.** It consists of a number (8 to 10) of rows of cells directly continuous with those from the rete mucosum of the epidermis. The outer cells are columnar ; those more internal become polyhedral.

The **inner coat** is called the inner **root sheath,** and consists of two layers. The outer of these is called *Henle's layer*, and is composed of a layer of elongated, nonnucleated, granular polyhedral cells. The inner layer is called *Huxley's layer*, and is composed of one or two layers of polyhedral cells containing granules of eleidin and small nuclei. The inner cells of Huxley's layer rests directly upon the cuticle of the hair root.

The **arrectores pilorum** are small bundles of smooth muscle-fibers which extend from the fibrous coat of the hair follicles to the upper surface of the corium.

The contraction of these muscles raises the hair from an oblique to a vertical position.

THE NAILS.

The **nails** consist of three portions—the *root*, the *body*, and the *free margin*.

The **nail groove** surrounds the root and sides of the body, the free margin projecting beyond the finger tips.

The floor of the nail groove upon which the body rests is called the **nail bed,** that portion supporting the root being called the **matrix.**

The nail groove has the same structure as the skin.

The nail bed consists of a prolongation of the corium, the upper surface of which is thrown into longitudinal ridges (instead of papillæ, as in the skin) that are covered by a number of layers of epithelial cells, resembling and continuous with the stratum Malpighii of the skin.

The nail is virtually a greatly hypertrophied stratum lucidum which is formed only above the matrix and pushed forward as the cells of the matrix multiply.

QUESTIONS FOR CHAPTER XIII.

279. What does the cutaneous system embrace?

280. Name the two portions of the skin.

281. Describe the stratum Malpighii.

282. What are prickle cells?

283. Describe the stratum granulosum.

284. Describe the stratum lucidum; stratum corneum.

285 Describe the corium.

286. What are the papillæ?

287. Describe the sebaceous gland.

288. Describe the sweat-gland.

289. Name the divisions of the hair.

290. Describe the shaft. Describe each layer separately.

291. What layers compose the hair follicles? Describe each separately.

292. What are the arrectores pilorum?

293. Name the three portions of the nails.

294. Describe the nail groove, the nail bed, and the matrix.

CHAPTER XIV.

THE EYE.

THE **eye** consists of the *anterior* and the *posterior chambers*, which are separated by the *iris* and *lens*.

The **anterior chamber** is limited in front and at the sides by the transparent cornea; posteriorly by the iris and lens.

The **posterior chamber** is surrounded by the retina, the choroid, and the sclera.

The **retina** covers the posterior portion of the inner surface of the eye and extends nearly to the ciliary body, where it terminates in a ragged edge, called the **ora serrata.** In the center of the retina, posteriorly, is an elevated spot, the **macula lutea**, in the center of which is a slight depression, called **fovea centralis.**

The **choroid** surrounds the retina externally, is pierced centrally by the optic nerve in its passage to the retina, and terminates in front in the ciliary process and iris.

The **sclera** is continuous posteriorly with the sheath of the optic nerve, passes forward, and joins the cornea near the latitude of the iris. Just before its junction with the cornea it is joined by a reflection of the *conjunctiva*, the epithelium of which becomes modified and continues over the remaining anterior portion of the sclera and the entire cornea.

The **lens** is a biconvex, transparent body, situated immediately behind and in contact with the iris, and is held in position by the **suspensory ligaments** which are attached to the ciliary body.

The anterior chamber is filled with a clear fluid, the **aqueous humor.**

The posterior chamber contains a thin, transparent, jelly-like substance, called the **vitreous humor.**

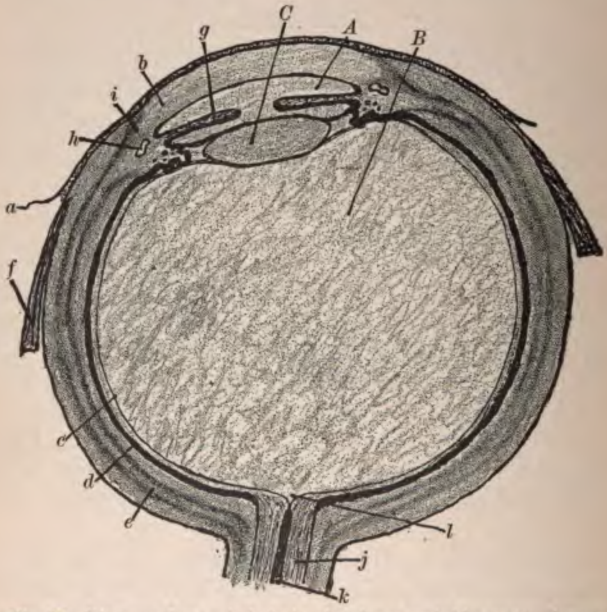

Fig. 75.—Diagram of eye: *A*, Anterior chamber occupied by aqueous humor; *B*, posterior chamber occupied by vitreous; *C*, crystalline lens; *a*, conjunctiva; *b*, cornea; *c*, retina; *d*, choroid coat; *e*, sclerotic coat; *f*, rectus internus muscle; *g*, iris; *h*, canal of Schlemm; *i*, corneoscleral junction; *j*, optic nerve; *k*, central artery; *l*, fovea centralis.

The **cornea** contains five layers, which, named from without inward, are the anterior epithelium, the anterior limiting membrane, the substantia propria, the posterior limiting membrane, and the posterior endothelium.

The **anterior epithelium** is a stratified epithelium, the innermost cells of which are cuboid, becoming flatter as they progress outward until the outer layers are squamous.

The **anterior limiting membrane, anterior elastic lamina,** or **membrane of Bowman,** is a moderately thick basement membrane, consisting of specialized fibrous tissue.

The **substantia propria** constitutes the main bulk of the cornea, and is composed of obliquely arranged bundles of fibrous tissue, which are bound together by clear cement substance (interfibrillar cement substance) and a few white fibers, which are called the **fibræ arcuatæ.**

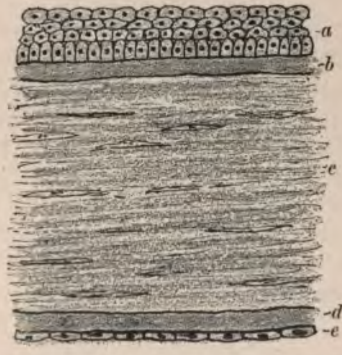

Fig. 76.—Cornea: *a*, External epithelium; *b*, anterior elastic lamina; *c*, substantia propria; *d*, posterior limiting membrane; *e*, posterior epithelium.

Between the fiber bundles and in the cement substance lie large numbers of irregular stellate lymph-spaces (the *lacunæ*, or *corneal spaces*), which are joined by a network of small canaliculi. In these spaces, and following their general outline, lie the *corneal corpuscles*, which unite by their stellate processes.

The **posterior limiting membrane, posterior elastic lamina,** or **Descemet's membrane,** is a thin, clear membrane, resembling the anterior limiting membrane.

The **posterior endothelium,** or **Descemet's endothelium,** consists of a single layer of flat endothelial cells, resting directly on the posterior elastic lamina.

After birth, the cornea contains no **blood-vessels** excepting in a narrow zone (the limbus), just at its periphery.

Lymphatic spaces occur in the lacunæ and canaliculi, and also around the large nerves.

The **nerves** are branches of the ciliary nerves, enter the substantia propria as medullated fibers, which at once lose their medullary sheath and form a network beneath the anterior epithelium, called the **subepithelial plexus,** which send still finer branches between the epithelial cells, called the **intra-epithelial plexus.** A few branches are also sent into the posterior portion of the substantia propria.

THE RETINA.

The **retina** may be divided structurally into three parts—the retina proper, the macula lutea with the fovea centralis, and the ora serrata.

The **retina proper** contains ten layers. Named from within (in contact with the vitreous humor) outward (to the choroid coat), they are—

1. Internal limiting membrane.
2. Layer of nerve-fibers.
3. Layer of ganglion cells.
4. The inner molecular, granular, or reticular layer.
5. Inner nuclear layer.
6. Outer molecular, granular, or reticular layer.

7. Outer nuclear layer.
8. External limiting membrane.
9. Layer of rods and cones.
10. Pigment layer, pigmented epithelium of the retina, or the tapetum nigrum (forming also the inner coat of the choroid).

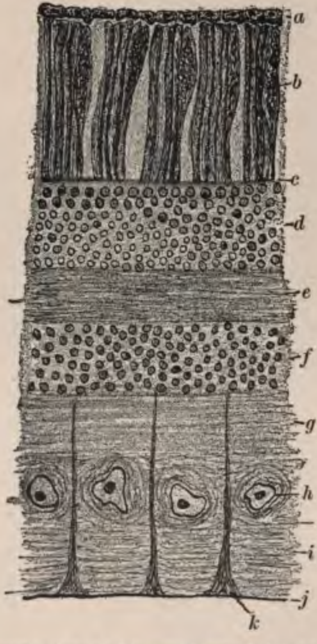

Fig. 77.—Section of retina: *a*, Pigment layer; *b*, layer of rods and cones; *c*, external limiting membrane; *d*, outer nuclear layer; *e*, outer molecular layer; *f*, internal nuclear layer; *g*, internal molecular layer; *h*, layer of ganglion cells; *i*, layer of nerve-fibers; *j*, internal limiting membrane; *k*, fibers of Müller.

The **radiating fibers of Müller** are large, very irregular columnar fibers, which are arranged vertically to the inner surface of the retina, and serve to form neuroglia framework for the support of the several layers which they transverse. They extend from the internal limiting membrane through all the various

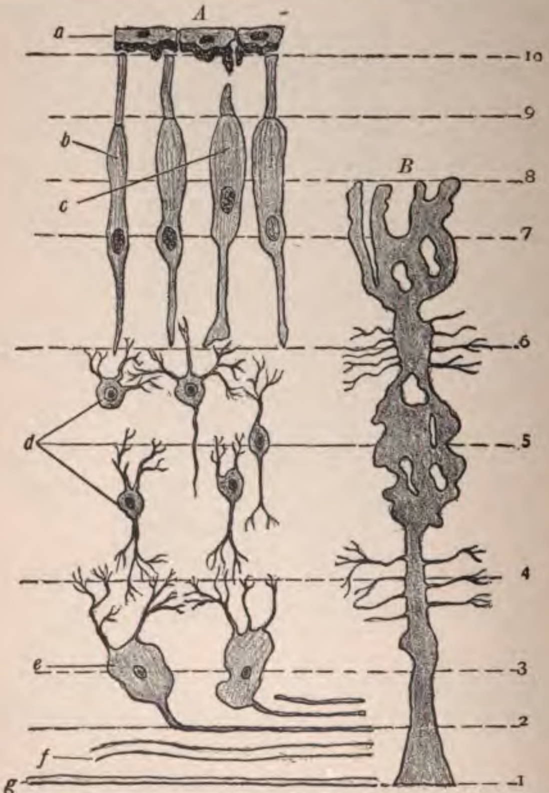

Fig. 78.—Diagram of retina: *A*, Elements of the retina; *B*, fiber of Müller, drawn to same scale, dotted lines indicating structure of fiber corresponding to retinal elements at same level. *a*, Pigment cells; *b*, rod cells and cones; *c*, cone cells; *d*, nerve-cells of inner nuclear layer; *e*, ganglion cells; *f*, fibers of nerve-fiber layer; *g*, internal limiting membrane, formed by approximated bases of fibers of Müller.

layers to the inner side of the layer of rods and cones, the internal ends of which they envelop.

In character they are greatly modified, enlarged, and elongated epithelial cells, each fiber having an oval nucleus at about the level of the inner nuclear layer.

The **internal limiting membrane** is a thin layer of apparently structureless tissue which is formed by the bases of the fibers of Müller joining for a short distance.

The **nerve-fiber layer** is composed of numbers of naked axis-cylinder fibers, the radiating continuations of the fibers of the optic nerve. These fibers, after running a varying distance in the nerve-fiber layer, turn upward nearly at right angles and enter the layer of ganglion cells. The **layer of ganglion cells** contains usually a single layer of large ganglion cells whose axis-cylinders are continuous with the fibers of the nerve-fiber layer. The outer sides of the cell give off dendritic processes, which branch and extend into the inner molecular layer.

The **inner molecular layer** consists of a tangled fibrillar mass of neuroglia tissue from the fibers of Müller, interspersed with the processes of the nerve-cells in the ganglion layer and the inner nuclear layer.

The **inner nuclear layer** contains some branches from and the nuclei of the fibers of Müller, together with three types of nerve-cell and their processes.

The inner layer of these nerve-cells is multipolar, sending its processes into the inner molecular layer.

The second type of cell is arranged in several layers and sends its processes into both the inner and outer molecular layers.

The external layer of nerve-cells is composed of stellate ganglion cells (that have been called spongioblasts or amacrines); they send axis-cylinder processes into the inner molecular layer and protoplasmic processes into the outer molecular layer.

The **outer molecular layer** is composed of the neuroglia and nerve-cell processes, between which are situated a few ganglion cells (the subepithelial ganglion cells), some of which lie horizontally, their axis-cylinder fibers running in the same direction and ending in arborizations beneath the rods and cones, and their protoplasmic fibers stopping at the outer nuclear layer, the other cells lying vertically and sending processes down into the inner nuclear layer.

The **outer nuclear layer** contains a clear matrix, mostly derived from the outer terminations of the fibers of Müller, embedded in which are the inner ends of the rods and cones with their nuclei.

The **external limiting membrane** is a thin membrane derived from the matrix of the outer nuclear layer, and is pierced by the cells of the rods and cones.

The **layer of rods and cones** contains, as its name implies, two types of cell, which extend from the outer or pigmented epithelial layer through the internal limiting membrane, and constitute part of the outer nuclear layer.

The rods and cones are neuro-epithelial cells, and are called the visual cells.

They occur alternating irregularly, being present in the proportion of about three or four rods for each cone.

The rod cells consist of two portions—an outer and inner. The outer portion occupies the true layer of rods and cones, and is subdivided into two portions. The outer subdivision is a homogeneous cylindric rod, which is colored a purplish tint by a substance called the visual purple, or rhodopsin, which soon becomes bleached upon being exposed to the light.

The inner subdivision is slightly enlarged, and is longitudinally striated at its outer margin, becoming granular near the outer limiting membrane.

As the rod cell passes through the outer limiting membrane it rapidly narrows to a fine filament having an enlargement somewhere near the center containing the nucleus of the rod. This portion of the rod lies in the outer nuclear layer, and constitutes the inner portion of the rod above mentioned.

The **cone cells,** like the rods, penetrate the outer limiting membrane, and contain an outer portion in the true layer of rods and cones and an inner portion in the outer nuclear layer.

The outer portion is likewise subdivided, the outer subdivision being shorter than the corresponding portion of the rod cell, and is conical. The inner subdivision is slightly broader and finely striated. The outer portion internal to the limiting membrane rapidly narrows to a fine filament containing an enlargement and nucleus near the limiting membrane.

The **pigment layer** consists of a single layer of large epithelial cells, the outer half of which is clear and contains the nucleus. The inner half contains many black granules of a pigment called fuchsin.

The **macula lutea** differ from the retina proper in the following respects: (1) The layer of nerve-fibers is incomplete; (2) the ganglion cells are very numerous and arranged in several layers; (3) rod cells are absent; (4) the entire structure is stained a distinct yellowish color.

The **fovea centralis** is depressed until at its fundus only the visual cone cells are left resting upon the pigment cells.

The **ora serrata** is irregular in outline and becomes thinner abruptly. In it the nerve-fibers and ganglionic layers are absent, the two molecular layers terminate and the fibers of Müller become very prominent.

The layer of pigment cells continues slightly modified as the outer lamina and the remaining layers dwindle down to a layer of columnar cells forming the inner lamina of the pars ciliaris and the pars iridica retinæ, which are recovered internally by a thin membrane or cuticle.

The **blood-supply** is derived from the arteria centralis retinæ, which enters through the center of the optic nerve and branches out to form an inner broad network of capillaries in the nerve-fiber layer and a finer network in the inner nuclear layer. The neuro-epithelium is nonvascular and receives its nutrition from the vessels of the choroid coat.

THE CHOROID.

The **choroid coat** contains four layers.

The first and most internal is the layer of **pigment cells,** which is common to both the choroid and the retina.

The next is the **glassy lamina,** or **vitreous membrane,** an apparently structureless, hyaline membrane upon which the pigment layer rests.

External to this is the thin capillary layer, or **choriocapillaris,** consisting of a thin, fibrous stroma, containing a close, capillary network continuous with the terminal branches of the ciliary artery.

The last layer is by far the thickest, and is called the **stroma.** It is composed of white, fibrous and yellow, elastic fibers, between which are large numbers of branched, darkly pigmented cells, which give the coat its black appearance. This layer is very vascular, the outer portion containing large vessels. As the inner portion of the layer is approached, the vessels become smaller in size until, near the junction of the chorio-capillaris, they are quite small, the surrounding stroma being devoid of pigment cells and forming a thin **boundary zone.**

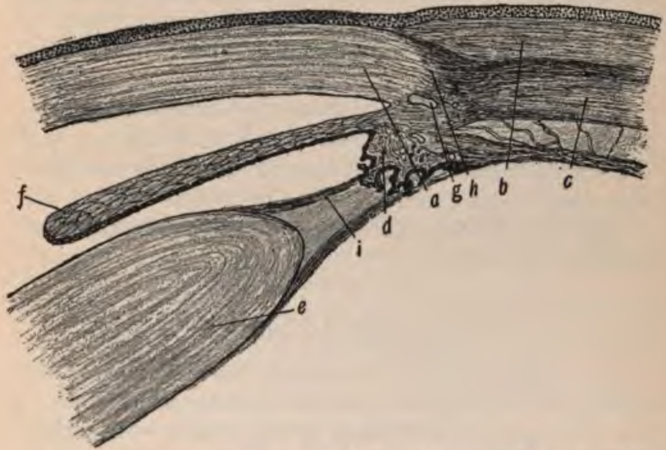

Fig. 79.—Corneoscleral junction: *a*, Cornea; *b*, conjunctiva; *c*, sclera; *d*, ciliary body; *e*, lens; *f*, iris; *g*, canal of Schlemm; *h*, point of the junction of the cornea and sclera; *i*, suspensory ligament of lens.

A small number of nonmedullated **nerve-fibers** are found being distributed to the blood-vessel walls.

Small perivascular **lymph-spaces** are occasionally seen around the veins of the stroma.

SCLERA.

The **sclera** contains three layers:

The innermost consists of a layer of **endothelial cells,** which separates it and the choroid.

The **middle layer** constitutes the bulk of the coat, and is composed of dense, white fibers and yellow, elastic fibers, supporting many fixed and wandering connective-tissue cells. The innermost portion of this is somewhat looser in texture, contains numerous branched pigmented cells, and is called the **lamina fusca scleræ.** This layer is also continuous, anteriorly, with the substantia propria of the cornea.

The outer layer of the sclera is a layer of endothelial cells.

A few small **blood-vessels** are present which present no characteristic distribution.

Lymph-spaces communicating with one another occur surrounding the cells.

Only a few naked axis-cylinders of **nerve-fibers** are found in the sclera.

THE CILIARY BODY.

The **ciliary body** lies on the inner surface of the eyeball, at the anterior portion of the posterior chamber. It may be divided into three portions—the ciliary ring, the ciliary processes, and the ciliary muscles.

The **ciliary ring** is a continuation of the choroid coat, extending from a point below the ora serrata to the ciliary processes. It differs in structure from the choroid in containing numerous smooth muscle-fibers from the ciliary muscle, has but little elastic tissue, and the choriocapillaris is absent.

The ciliary processes constitute the inner surface of the ciliary body, and consist of fibrous stroma which is thrown into a large number (60 to 80) of circular folds.

These are covered internally by a thin, transparent membrane, continuous with the glassy lamina of the choroid.

Internal to this is a row of darker pigmented cells, which, in turn, are covered by a layer of columnar cells, internal to which is a thin, transparent, internal limiting membrane. All of these last three layers are continuous with the similar layers of the retina.

The **ciliary muscle** lies external to the ciliary processes, and contains smooth muscular fibers, which are arranged in three directions, and which in contracting, change the form of the lens in the process of accommodation.

The outer layer of fibers run parallel to the sclera, and are called the meridional fibers.

Below these, posteriorly and running at a slight angle, are the **radial fibers.**

In front of the radial fibers a smaller number of fibers run circularly around the ciliary body. These are called the **circular fibers.**

Lying in the sclera, about at the junction of the cornea, sclera, and ciliary bodies, is a small oval, venous channel, called the **canal of Schlemm.**

The **blood supply** is not prominent, being distributed chiefly to the ciliary muscle-fibers.

A small plexus of medullated *nerve-fibers* is found in the ciliary body, from which small branches pass to the eye and cornea. A small number of ganglion cells also occur.

THE IRIS.

The **iris** extends from the anterior edge of the ciliary body, between the anterior and posterior chambers of the eye. It consists of five layers—anterior endothelium, anterior boundary layer, vascular layer, posterior boundary layer, and pigment layer.

The **anterior endothelium** is a single layer of flat, granular endothelial cells, which are continuous with the posterior endothelium of the cornea.

The **anterior boundary layer** consists of meshworks of fibrous tissue, entangling large numbers of lymphoid cells, the whole resembling adenoid tissue.

The **vascular layer** composes the main bulk of the iris, and is composed of loose fibrous tissue, in which lie a radiating plexus of arteries and two sets of smooth muscular fibers. The iris is surrounded by an artery (the *circulus iridis major*), from which the above-mentioned radiating plexus arises and converges to a smaller arterial ring at the margin of the pupil (the *circulus iridis minor*).

The muscles are arranged in two sets. The inner forms a ring around the pupil, which it narrows upon contraction ; the other set is arranged radially and, upon contracting, serves to dilate the pupil.

The **posterior boundary layer**, or **vitreous lamella**, consists of a thin structureless membrane, which seems to support the pigment cells.

The pigment layer consists of the following layers : The anterior is a layer of spindle-shaped cells, which are arranged radially and are more or less pigmented. The middle layer is thicker, and consists of cells much more darkly pigmented, so that their outline is lost ; the amount of the pigment in this as well as that of the anterior layer depending upon the color of the eyes, being absent in albinos.

The *inner layer*, *cuticular membrane*, or *membrana limitans iridis*, is a very thin membrane.

These layers of the pigment layer are continuous with the pigment layer of the ciliary processes.

The *nerves* in the iris lose their medullary sheath, and are distributed to the circular and radiating muscular fibers.

THE LENS.

The **lens** is a transparent, biconvex structure which lies immediately behind the iris.

It consists of a lenticular mass of lens fibers, covered on its anterior surface by the lens epithelium, the whole being surrounded by a capsule and retained in position by the suspensory ligament.

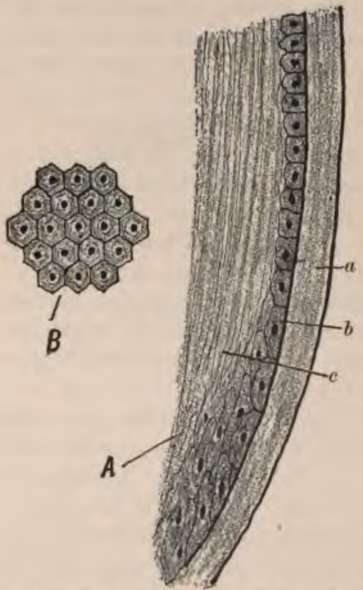

Fig. 80.—**Lens**: *A*, Fibers longitudinal; *a*, anterior capsule; *b*, anterior epithelium; *c*, lens fibers. *B*, Posterior surface view of anterior epithelium.

The **capsule** consists of a thin membrane of elastic tissue, thicker in front than behind, into which the fibers of the suspensory fibers merge.

The **lens epithelium** consists of a single layer of cuboid cells covering the anterior surface of the lens, and lying just beneath the capsule. At the edge of the lens these cells become much elongated and merge into the lens fibers.

The *lens fibers* constitute the bulk of the lens, and consist of long, clear, hexagonal fibers, extending from the edge to the center of the lens. The fibers are nucleated near the edge, the remainder being perfectly clear and transparent. They are held together by a clear cement substance, which is reinforced in the central zone, the fibers there being serrated by a dovetailing of the edges. As the fibers do not completely encircle the lens, there are places where the ends of the fibers abut, which form the stellate areas called the **lens stars.** Two of these occur, the anterior and the posterior.

The **suspensory ligament**, the **zonula ciliaris**, or **zone of Zinn**, consists of thin fibers which begin at the ora serrata (where they are continuous with the hyaloid membrane of the vitreous body) and, extending over the ciliary processes to which they are attached, pass to the lens. Just before reaching the lens the fibers separate, part going to the anterior portion of the edge and part to the posterior portion of the edge. In this way a small triangular space is left surrounding the lens and bounded by the two portions of the suspensory ligament. This space has been called the **canal of Petit.**

THE AQUEOUS HUMOR.

The **aqueous humor** consists of a clear fluid in which a few leukocytes may be found.

THE VITREOUS HUMOR.

The **vitreous humor** consists of a very loose network of delicate fibrils and branching cells, the meshes of which are greatly dilated by the clear jelly-like vitreous substance. It is surrounded by a slightly denser membrane of fibrous tissue which, anteriorly, is continuous with the suspensory ligament, and is called the **hyaloid membrane.** Occasional leukocytes are also found both in the hyaloid membrane and in the body of the vitreous.

THE EYELIDS.

The **eyelids** consist of five layers—the skin, muscular layer, median connective tissue, tarsal plate, and conjunctiva.

The **skin**, with its subcutaneous tissue, has the same structure as elsewhere, being, however, quite thin.

The **muscular layer** consists of irregular bundles of voluntary muscle-fibers from the orbicularis palpebrarum.

The **median connective-tissue layer** consists of fibrous tissue, containing occasional smooth muscle fasciculæ.

The *tarsal plate* consists of fibrous tissue much denser than the latter, embedded in which lie a number of long, compound tubular glands (the *Meibomian glands*), which secrete a fatty substance just internal to the eyelashes.

The **conjunctiva** covers the inner surface of the eyelid, and is reflected over upon the eyeball at a point near the corneoscleral junction. It is composed of a basement membrane covered by epithelium, which at the inner surface of the lid is stratified, columnar, and continuous with that of the skin. Near its junction with the sclera the cells become flattened and continue over the cornea as the anterior epithelium.

THE LACRIMAL GLANDS.

The **lacrimal glands** are small racemose glands of the serous type, which are situated at the upper outer angle of the orbit. Their secretion is poured upon the surface of the conjunctiva by a number of small canals.

QUESTIONS FOR CHAPTER XIV.

295. Name the chambers of the eye. What separates them?

296. Give the boundaries of the anterior chamber; of the posterior chamber.

297. Describe the gross structure of the retina, of the choroid, of the sclera, of the lens, and of the cornea.

298. Name the layers of the cornea. Describe each separately.

299. Describe the lymphatic and nerve supply of the cornea.

300. Name the three parts of the retina.

301. Name the ten layers of the retina in their order.

302. Describe each layer of the retina.

303. What are the radiating fibers of Müller?

304. Describe the macula lutea.

305. Describe the fovea centralis.

306. Describe the ora serrata.

307. Describe the blood supply of the retina.

308. Name the four coats of the choroid. Describe each separately.

309. Describe the nerve, lymphatic, and blood supply.

310. Name the three layers of the sclera. Describe each.

311. What is the ciliary body? Describe its structure.

312. What is the canal of Schlemm? Give its location.

313. What is the nerve and blood supply?

314. Name the five layers of the iris. Describe each.

315. Give the general structure of the lens.

316. What are the lens stars?

317. Describe the suspensory ligaments.
318. Describe the aqueous humor.
319. Describe the vitreous humor.
320. Name the layers of eyelids and describe each.
321. Describe the lacrimal glands.

CHAPTER XV.

THE EAR.

THE **ear** may be divided into three portions—the external ear, the middle ear, and the internal ear.

The **external ear** consists of the pinna, or auricle, and the auditory canal.

The *pinna,* or *auricle,* consists of a basis of yellow elastic cartilage, which is covered by the skin and its subcutaneous tissue. In the inner surface are found coiled tubular glands, which are modified sweat-glands, and secrete a waxy substance. These are called the *ceruminous glands.*

The *auditory canal* is a little over an inch in length, extending inward to the tympanum.

The outer half of the canal is composed of cartilage continuous with that of the pinna. The inner half is osseous in structure. The entire canal is lined with a thin stratified epithelium, containing a few hairs and ceruminous glands near the outer portion of the canal.

The **middle ear** includes the tympanum, the Eustachian tube, the mastoid cells, and the tympanic cavity, with the small ear bones, or ossicles.

The *tympanum* consists of three layers. The *external layer* is a thin, stratified epithelium, continuous with the lining of the auditory canal.

The *middle layer* is a thin membrane of white, fibrous tissue.

The *internal* or *mucous layer* consists of a single layer of cuboid epithelial cells, continuous with the lining of the tympanic cavity.

Blood-vessels, *lymphatics*, and *nerves* are very numerous.

The *Eustachian tube* consists of three portions. The inner, opening into the tympanic cavity, has bony walls; the middle portion, yellow, elastic, cartilaginous walls; and the portion opening into the pharynx is fibrous. The entire tube is lined by stratified, ciliated, columnar epithelium.

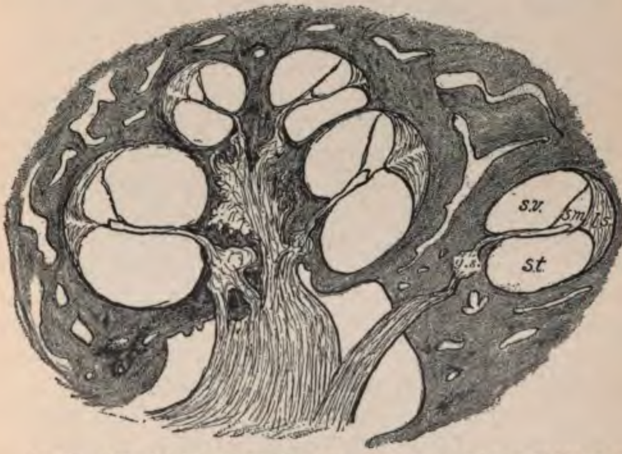

Fig. 81.—Longitudinal section of cochlea, showing the relation of the scalæ, the ganglion spiralæ, etc. (after Gray): *s. v.*, Scala vestibuli; *s. t.*, scala tympani; *s. m.*, scala media; *l. s.*, ligamentum spirale; *g. s.*, ganglion spirale.

The *tympanic cavity* and *mastoid cells* are lined by their periosteum, upon which is a thin layer of fibrous tissue supporting the epithelium. This and the mastoid cells and the promontory are flat, and but a single layer in thickness. Over the other portions of the cavity the epithelium is columnar-ciliated.

The *ossicles* have the usual structure of compact bone, being covered at their articulations with hyaline cartilage.

The **internal ear**, or **labyrinth**, comprises the vestibule, semicircular canals, the cochlea, and the membranous labyrinth.

The *vestibule* and *semicircular canals* are lined by a very thin fibroserous membrane, which secretes a thin fluid—the perilymph.

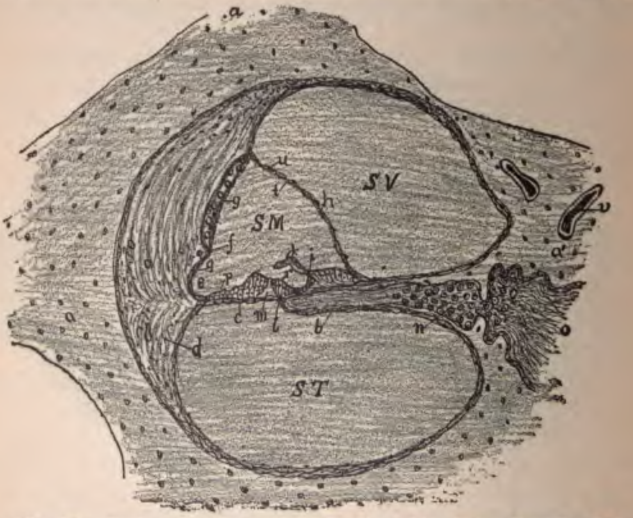

Fig. 82.—Section of a single turn of cat's cochlea (after Piersol): ***S V***, ***S M***, *S T*, Scala vestibuli, media, and tympani; *a*, *a*, *a*, osseous tissue projecting as spiral lamina (*b*); *c*, basilar membrane attached to spiral ligament (*d*) on outer wall; *e*, concave surface lined by flat cells (*q*), interrupted by spinal prominence (*f*) containing blood-vessels; *g*, striæ vascularis; *h*, Reissner's membrane covered by epithelium (*t*) of cochlear duct and by endothelium (*u*) of scala vestibuli; *i*, limbus from which extends membrana tectoria (*k*) overhanging Corti's organ; *m*, tunnel of Corti; *r*, *s*, inner and outer hair cells; *p*, cells of Claudius; *n*, spiral ganglion; *o*, nerve bundles; *v*, blood-vessels.

The *perilymph* fills the space between the walls and the membranous labyrinth.

The *membranous labyrinth* has three portions—the saccule, the utricle, and that portion in the semicircular canals. All, however, have a similar structure consisting of three layers. The outer is of fibro-elastic tissue, the middle layer a delicate basement membrane, and the inner a single layer of squamous epithelium.

At certain areas marking the entrance of the auditory nerve-fibers the membrane is much thickened, the epithelium covering these areas becoming columnar, until at the end of the nerve-fibers the neuro-epithelium is reached. These spots are called the maculæ cribrosæ in the saccules and utricles, and the cristæ acusticæ in the semicircular canals. The neuro-epithelium is of two kinds—fiber cells and hair cells.

The *fiber cells* are long, slightly hourglass-shaped elements, the bottom expansion being slightly larger than the upper. They have good-sized oval nuclei situated in the lower portion. These cells serve as supporting elements.

The *hair cells* are more cylindric elements, situated between the fiber cells. They have a large spheric nucleus, and their free surface is covered by long, delicate filaments, called the *auditory hairs*. The hair cells are the special endings of the auditory nerve.

Upon the surface of the hair cells a gelatinous substance is spread, in which are embedded numerous slightly elongated crystals of calcium carbonate, called the *otoliths*, or *ear stones*.

The center of the membranous labyrinth is filled with a clear fluid, which is called the *endolymph*.

THE COCHLEA.

The **cochlea** consists of a small tube coiled spirally two and a half times around a central pillar (the modiolus).

The **modiolus** contains the fibers of the cochlear branches of the auditory nerve-fibers from which they pass into the spiral tube.

The **spiral tube** contains a long spiral lamina, which extends as a shelf from the modiolus to its center.

From the free edge of this bony lamina a triangular duct (the **membranous cochlea** or **ductus cochlearis**) extends, its base being attached to the periphery of the bony tube.

This arrangement constitutes virtually three tubes; that above the bony lamina is called the *scala vestibuli*, that within the ductus cochlearis is called the *scala media*, that below is called the *scala tympani*.

The membrane forming the boundary between the scala vestibuli and the scala media is called the *membrane of Reissner*, or *membrana vestibularis*. That between the scala tympani and the scala media has received the name of the *membranous spiral lamina*.

The **scalæ vestibuli** and the **tympani** are lined by the periosteum, which is considerably thickened at the periphery or point of attachment of the ductus cochlearis, and is called in this location the *ligamentum spirale*.

The **membrane of Reissner** consists of three layers: that bounding the scala is of epithelium; the middle layer is of thin fibrous tissue; that layer lining the scala media is a single layer of squamous epithelium.

The **membranous spiral lamina** also has three layers—the tympanic lamella, the basilar membrane, and the epithelium.

The **tympanic lamella** forms part of the lining of the scala tympani, and consists of a dense layer of fibrous tissue, the outer surface of which is covered by fusiform cells of undeveloped mesoblastic nature.

The **basilar membrane** forms the supporting portion of the membranous spiral lamina, and is composed of fibrous tissue.

The **epithelium** covering the peripheral portion of the spiral lamina is flat and slightly granular. These cells are termed the **cells of Claudius**, and the area covered by them the **zona pectinata.**

At the inner portion the cells become greatly specialized and form a mass called the *organ of Corti,* the area covered by it being known as the zona tecta.

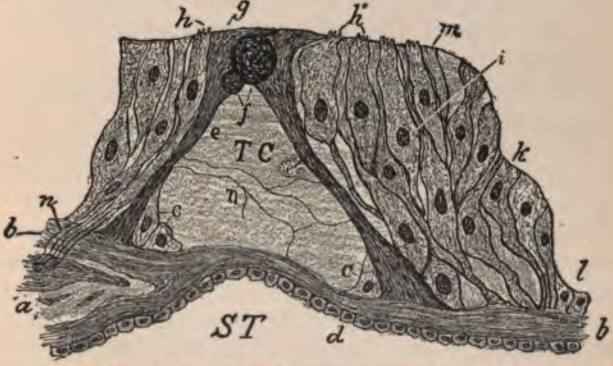

Fig. 83.—Section of Corti's organ from guinea-pig's cochlea (after Piersol): *ST,* Scala tympani; *TC,* tunnel of Corti; *a,* bony tissue or spiral lamina; *b, b,* fibrous tissue covering same continued as substantia propria of basilar membrane; *c, c,* protoplasmic envelope of Corti's pillars (*e, e*); *d,* endothelial plates; *f,* heads of pillars containing oval areas; *g,* head plates of pillars; *h, h',* inner and outer hair-cells; *m,* membrana reticularis; *k, l,* cells of Hensen and Claudius; *n, n,* nerve-fibers; *i,* cells of Deiters.

The **organ of Corti** consists of numerous arches of epithelial cells, joined side by side to form a long tunnel, which extends nearly the whole length of the cochlea.

Several types of epithelial cells contribute to the formation of the organ.

On either side of the arch proper, and really forming part of it, are the *pillar cells.* These are tall, narrow cells with expanded bases, and, according to their position, are known as outer or inner pillar cells.

The inner cells are somewhat the shorter of the two and have a concave upper outer surface, into which the convex adjoining surface of the outer cell fits. The tunnel thus formed contains a clear, thick fluid, through which many nerve-fibers pass.

Just internal to the inner pillar cells is a row of shorter, tailed columnar cells (one cell wide in each arch). These cells have a number of hair-like projections on their free end, and are called the **inner hair cells.**

Still internal to these are a number of columnar cells which serve as inner sustentacular cells.

External to the outer pillar cells three or four rows of hair cells occur, which resemble the inner hair cells, but are called the **outer hair cells.**

Situated below these cells, and sending up slender prolonged ends separating the outer hair cells from each other, are a few fusiform cells, called the **cells of Deiters.** Between these cells spaces frequently occur which communicate with the tunnel and contain a clear fluid, and are called Nuel's spaces.

External to the cells of Deiters are a few cells intermediate in size, which gradually merge with the cells of Claudius, and which are called the cells of Hensen.

The **nerves** branch continually from the modiolus, fibers passing into the **ganglion spiralæ** which are situated just within the bony spiral lamina. From this the fibers pass to the inner hair cells, and thence across the tunnel to the outer hair cells.

The *blood supply* of the cochlea consists of a number of branches from the cochlear branch of the auditory artery. Some of these branches supply the lower portion of the cochlea, the rest passing up the modiolus, where some of them coil up to form the *glomeruli cochleæ*; others proceed to the membrane of Reissner. Branches from the glomeruli pass into the membranous spiral lamina.

The fluid in the perilymph-spaces of the entire inner ear intercommunicate, and are also in connection with subarachnoid lymph-spaces. The endolymph-spaces likewise communicate with each other and with subdural spaces.

QUESTIONS FOR CHAPTER XV.

322. Name the three portions of the ear.

323. Describe the structure of the auricle; the auditory canal.

324. What is included in the middle ear?

325. Describe the three layers of tympanum.

326. Describe the Eustachian tube.

327. Describe the structure of the tympanic cavity and the mastoid cells.

328. Describe the structure of the ossicles.

329. What structures comprise the internal ear?

330. Describe the structure of the vestibule and the semicircular canal.

331. Describe the structure of the membranous labyrinth.

332. What is the perilymph?

333. What is the neuro-epithelium, the fiber cells, and the hair cells?

334. What are the auditory hairs? the otoliths?

335. Of what does the cochlea consist? What is the membranous cochlea?

336. What is the scala vestibuli? the scala media?

337. What is the membrane of Reissner? Describe it.

338. What is the membranous spiral lamina? Describe it.

339. What is the organ of Corti? Describe it.

340. What are the cells of Deiters?

341. Describe the nerve distribution of the internal ear.

342. What are the ganglion spiralæ ?

343. Describe the blood supply of the internal ear. What are the glomeruli cochleæ ?

344. Describe the lymph supply of the internal ear.

CHAPTER XVI.

THE NASAL MUCOUS MEMBRANE.

THE **nasal membrane** is divided into two parts—the respiratory and the olfactory tracts.

The **respiratory mucous membrane** is lined with stratified columnar, ciliated, epithelial cells, under which is a well-marked submucosa of loose fibrous tissue containing many glands and blood-vessels. The glands are tubular, and may be either serous or mucous in character. Many leukocytes are found surrounding the glands and scattered through the fibrous tissue, as well as occasionally invading the epithelial covering. Small lymph-nodes, or follicles, are seen quite frequently, as well as small, scattered masses of diffuse adenoid tissue.

The **olfactory mucous membrane** differs from the respiratory in color, being brownish and circumscribed, the color limit not, however, exactly marking the extent of the olfactory cells, which may continue into the apparently red of the respiratory membrane.

It consists of two layers—the epithelial tissue and the subepithelial tissue.

The **epithelial tissue** is stratified in character and contains three types of cell:

The *sustentacular cells* constitute the chief bulk of the epithelial layer, being cylindrical, with a round nucleus at the outer portion and an irregular, thin inner portion, which gives place to and surrounds the other elements.

The *olfactory cells* are long, very narrow cells, with a nuclear expansion containing a spheric nucleus, situated at varying distances from the end of the cell. The cells are situated at different levels between the sustentacular cells, and are in connection with delicate filaments of the olfactory nerve at their inner ends.

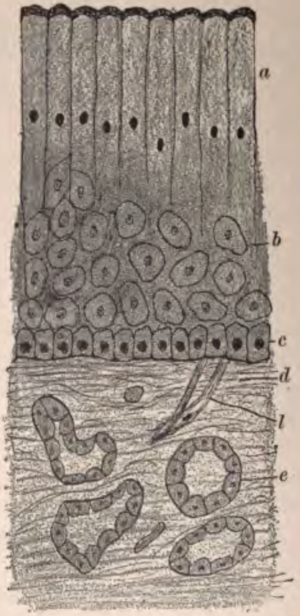

Fig. 84.—Olfactory mucous membrane: *a*, Sustentacular cells; *b*, olfactory cells; *c*, basal cells; *d*, submucous fibrous tissue; *e*, glands of Bowman; *l*, nerve-fibers.

The *basal cells* are a row of modified cuboid, sustentacular cells which lie immediately upon the subepithelial tissue.

The **subepithelial tissue** consists of a rather loose mixture of white fibrous and yellow elastic tissue, into which a number of branched tubular glands, called the *glands of Bowman*, extend.

The **blood-vessels** are usually found deeply situated in the subepithelial tissue, sending very numerous branches, however, to the tissue immediately under the epithelium as a capillary network.

The **lymphatics** are quite numerous, consisting of many nodes and follicles, with lymph-spaces in the upper portion communicating with the large lymph-vessels deeper in the tissue.

The **nerves** are both sensory and special sense, from the trifacial and olfactory nerves respectively. The fibers of the olfactory nerve are nonmedullated, and eventually communicate with the olfactory cells. The sensory fibers are medullated, and are distributed to the under layer of the epithelial, but not to the olfactory cells.

QUESTIONS FOR CHAPTER XVI.

345. What are the two divisions of the nasal mucous membrane?

346. Describe the structure of the respiratory mucous membrane.

347. What are the two layers of the olfactory mucous membrane?

348. Describe the sustentacular cells; the olfactory cells; the basal cells.

349. Describe the subepithelial tissue. What are the glands of Bowman?

350. Describe the blood-vessels of the nasal mucous membrane; the lymphatic; the nerves.

CHAPTER XVII.

THE CENTRAL NERVOUS SYSTEM.

THE SPINAL CORD.

THE **spinal cord** is continuous with the medulla oblongata, and extends downward in the spinal canal to the beginning of the lumbar region, at which locality it divides into a number of fibers, called the **fibræ terminales, chorda equina,** or **filum terminalæ.**

The cord is covered externally by three membranes,—the dura mater, the arachnoid, and the pia mater,—which serve as a support to itself and its blood-vessels.

The **dura mater** is the outermost of the membranes of the cord, and is composed of bundles of fibro-elastic tissue, interspersed with thin connective-tissue cells, granular cells, and narrow lymph-spaces. Most of its external surface is attached directly to the bone, but areas occur in which spaces exist containing lymph and lined by endothelium. These spaces are called the **epidural spaces.**

The inner surface of the dura mater is also covered with endothelium, excepting where it is united by small branches to the arachnoid.

The **arachnoid** lies internal to the dura, and, while in contact with it throughout most of its extent, is attached only by a few delicate fibers.

Between the two membranes occasional spaces exist, which are called the **subdural spaces.**

Other spaces also occur between the internal surface of the arachnoid and the pia mater, which are termed the **subarachnoidean** spaces. All the spaces of the arachnoid are covered by endothelium. Projecting upward into the subdural spaces occasional papillæ occur, which in certain localities are much enlarged, being then called the *Pacchionian bodies.*

The substance of the arachnoid is of much finer connective tissue than the dura, and its structure is very loose in texture.

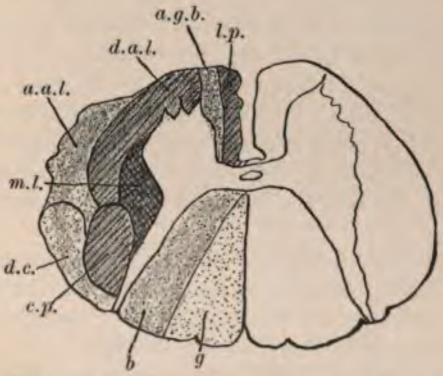

Fig. 85.—Spinal cord, cervical region (diagrammatic), showing secondary tracts of white matter, the dark area representing descending fibers, dotted area ascending fibers, cross-lined area mixed fibers, and clear area gray matter: *l.p.*, direct pyramidal tract; *a.g.b.*, anterior ground bundle; *d.c.*, direct cerebellar tract; *a.a.l.*, ascending anterolateral or Gower's tract; *c.p.*, crossed pyramidal tract; *d.a.l.*, descending anterolateral tract; *m.l.*, mixed lateral tract: *g*, column of Goll; *b*, column of Burdach.

Neither **blood-vessels** nor **nerves** occur in the arachnoid, but **lymph-spaces** are numerous.

The **pia mater** lies internal to the arachnoid, and is applied closely to the substance of the spinal cord. It presents two layers:

The *outer layer* is very vascular, is composed of fibrous tissue, and is covered on its external surface by endothelium, excepting where small fibers connect it with the arachnoid.

The *inner layer* is less vascular, and sends prolongations down into the substance of the cord, and between the anterior and the posterior fissure.

A few scattered nonmedullated nerve-fibers occur.

The substance of the cord is composed of white matter and gray matter.

The **gray matter** is arranged in the form of an **H**-shaped mass, situated in the central portion of the cord, and almost entirely surrounded by white matter. The two upright lines of the **H** are crescentic in outline, and run anteroposteriorly, so that the middle piece will lie transversely. The two anterior portions are slightly shorter and somewhat thicker than their posterior counterparts, and are called the anterior horns, in contradistinction to the latter, which are known as the posterior horns.

The **anterior horns** have numerous projecting processes pointing outward to the surface, but do not themselves extend as near to the anterior surface as do the posterior horns to the posterior surface.

The **posterior horns** are narrower, and in most localities extend to the posterolateral surface of the cord.

The middle piece of the **H** is termed the **gray commissure**, and contains in its center an opening which is lined with ciliated epithelium, and, being continuous with the ventricles of the brain, contains cerebrospinal fluid. This structure is called the **central canal**, and serves to divide the gray commissure into two parts, that in front of the canal being called the **anterior gray commissure**, and that behind the canal the **posterior gray commissure.**

The **white matter** surrounds the gray matter, giving a section of the cord a rather oval outline—broader or narrower, according to location. From the center of the periphery anteriorly a slight cleft extends into the substance of the cord, reaching nearly to the anterior gray commissure, which is called the **anterior median fissure.** Opposite this a slight cleft occurs on the posterior aspect which is continued nearly to the posterior gray commissure as a fibrous line, known as the **posterior median fissure.** Between the bottom of the anterior and posterior median fissures and the gray commissure are small bridges of white substance, called respectively the anterior and the posterior white commissures.

The two fissures and the horns of gray matter divide the cord into vertical columns, which have been termed the **primary columns.** The two masses of tissue on either side of the anterior median fissure and the anterior horns are called the *anterior columns.* That between the anterior and the posterior on the same side form the *lateral columns.* Both of the former taken together are sometimes known as the *anterolateral columns.* The white matter situated between the posterior fissure and the posterior horns is known as the *posterior column.*

Each of these columns is further subdivided into **secondary columns,** according to the distribution of the fibers composing it.

About half of the anterior columns (adjacent to the fissure) is composed of fibers running downward, and is called the **direct pyramidal tract,** or Türck's column. The remainder of the anterior column is composed of fibers carrying ascending impulses, and constitutes the **anterior ground bundle,** or **anterior fundamental column.**

The lateral column is divided into five tracts—the direct cerebellar, the ascending **anterolateral or Gowers'** tract, the crossed pyramidal, **the descending anterolateral**, and the mixed lateral.

The **direct cerebellar tract** occupies a narrow band at the posterior half of the surface of the lateral column. Its fibers are descending.

The **ascending anterolateral** or **Gower's tract** is situated just anterior to the direct cerebellar tract, and external to the anterior portion of the crossed pyramidal and the descending anterolateral tracts. Its fibers are ascending.

The **crossed pyramidal tract** lies internal to the direct cerebellar tract, its fibers being descending.

The **descending anterior lateral tract** lies internal to Gower's tract and anterior to the crossed pyramidal tract. Its fibers are descending.

The **mixed lateral tract** occupies a small space bounded internally by the gray matter and externally by portions of both the crossed pyramidal and the descending anterolateral tract. The mixed tract contains both ascending and descending fibers.

The posterior column is divided into two tracts—the column of Burdach and the column of Goll.

The **column of Goll, or fasciculus gracilis,** occupies a wedge-shaped area covering the median half of the posterior column. Its fibers are ascending.

The **column of Burdach,** or **fasciculus cuneatus,** occupies the remainder or lateral half of the posterior column. Its fibers are also ascending.

MINUTE STRUCTURES.

The **gray substance** consists of an intricate tangle of nerve-cells, nerve-fibers, and a specialized connective tissue, called the neuroglia.

The **nerve-cells** in the gray matter are arranged more or less in groups. In the anterior horns four groups may be recognized—the inner or median, the anterior, the anterolateral, and the posterolateral. At about the junction of the anterior and posterior horns, on the external side, an enlargement occurs, which in the dorsal region is most distinct, and is called the **lateral horn.** In the lateral horn a small group of nerve-cells occur. In the posterior horn the cells are more scattered, no constant grouping occurring, with the exception of a spot at the inner root of the horn, where the column of Clarke, a group of large cells, is found.

In the **anterior horn** and **column of Clarke** the nerve-cells are very large and stellate, sending off many processes in various directions, which branch repeatedly to form dense arborizations of fibrils, called **dendrites.** One of the processes, however, continues on

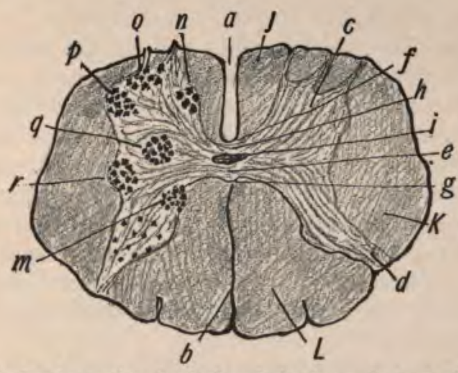

Fig. 86.—Lumbar section of spinal cord, showing main tracts of white substance and location of principal groups of nerve-cells in gray matter: *a*, Anterior median fissure; *b*, posterior median fissure; *c*, anterior horn of gray matter; *d*, posterior horn of gray matter; *e*, central canal; *f*, anterior white commissure; *g*, posterior white commissure; *h*, *i*, anterior and posterior gray commissures; *j*, anterior median column; *K*, lateral column; *L*, posterior column; *m*, column of Clarke; *n*, inner group of nerve-cells; *o*, anterior group; *p*, anterolateral group; *q*, posterolateral group; *r*, lateral horn.

and eventually becomes the axis-cylinder of a nerve-fiber, and is called the **axis-cylinder process, axon,** or **neuraxon.**

The ganglion cells themselves have large, clear vesicular nuclei, with usually a well-marked nucleolus in each cell. In the cell-body a greater or less amount of granules occur, which exhibit specific staining reactions. These granules vary in amount, location, and distribution in various cells, and appear to bear a relationship to the state of activity of the various cells previous to death. They have received the names of **chromatic granules of Nisel,** or **chromatophilic granules.**

In the posterior horn the cells are somewhat smaller and tend more to assume a fusiform outline, remaining, however, multipolar.

While the dendritic processes of the various cells interlace most intimately with one another as well as with the terminal arborizations of nerve-fibers whose cells are at a distance, still it would seem as though there was no structural union between the fibers of separate nerve-cells, any impulse passing from one cell to another apparently acting by contact of the fibers or through the minute spaces which separate them.

Beside the nerve-cells and their various processes, a small number of **medullated nerve-fibers** may be found in the gray matter.

The interstitial substance of both the white and the gray matter is composed of what is termed **neuroglia tissue.** This is a tissue composed of nucleated much-branching cells (the **glia cells**), of which there are two chief varieties—the spider cell and the mossy cell. In the **spider cells** the processes are long and delicate, branching but little. The **mossy cells,** on the contrary, have thick and short processes, which branch irregularly and are more in the gray matter.

At the base of the posterior horns, especially at the edges, a more open structure is found, which contains but few cells, called the **reticular process.** At the summit of the posterior horns a slightly enlarged mass of clear, jelly-like substance, consisting structurally mostly of neuroglia tissue, occurs, termed the **substantia gelatinosa Rolandi.** Posterior to this a small **zona spongiosa** occurs bounded by a narrow zone of vertical nerve-fibers, called the **zona terminalis.**

The **white substance** consists of a slight framework of fibrous tissue, extending from the pia mater, which supports large numbers of nerve-fibers, between which occur numerous glia cells.

The nerve-fibers have a medullary sheath, but are devoid of neurilemma. Most of the fibers run vertically,—that is, parallel to the long axis of the cord,—but many fibers may be found running obliquely, especially in front of the gray commissure.

The glia cells in the white substance are mostly of the spider variety, many of which have extra-long vertical branches (the chief processes), which run between the nerve-fibers, apparently serving the purpose of a neurilemma.

The **blood-vessels** enter the cord mostly in the fibrous septa from the pia mater, branch repeatedly, and become surrounded by a layer of neuroglia tissue. They eventually break up into capillaries, which run mostly longitudinally between the nerve-fibers in the white substance, but form a network in the gray matter.

THE CEREBELLUM.

The **cerebellum** consists of a gray and a white matter, the former being external.

The white substance is arranged in branching sheets, which are covered by the three layers of gray matter, and, when cut, presents in the cut section a tree-like arrangement, called the **arbor vitæ.**

The gray layers are respectively from within outward: the granule layer, ganglionic layer, or layer of Purkinje's cells, and the layer of gray substance proper, or molecular layer.

The **white substance** consists of great numbers of medullated nerve-fibers devoid of a neurilemma and held together by neuroglia tissue, the majority of the glia cells being of the spider variety.

The *granule layer* lies just external to the white substance, and is composed of two kinds of nerve-cells, and a supporting neuroglia tissue, and forms a rust-colored band about one-half the entire width of the gray substance. With ordinary methods of staining,

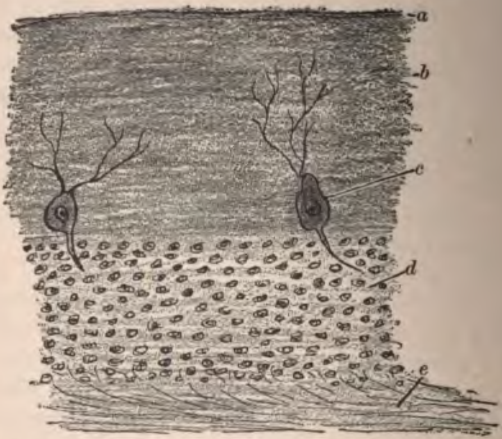

Fig. 87.—Section of cerebellum: *a*, pia mater; *b*, molecular layer; *c*, cell of Purkinje; *d*, granule layer; *e*, white substance.

all the cells of this layer resemble each other, having a relatively large nucleus and small cell-body. With special staining methods, such as that of Golgi, the two different types become apparent.

The first type was called the **small granule cell,** or multipolar, and has short, irregular, protoplasmic processes and a long axis-cylinder process.

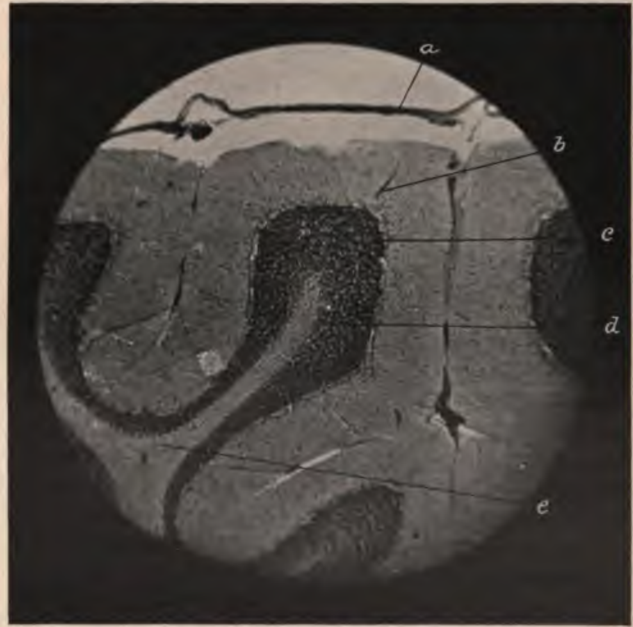

Fig. 88.—Cerebellum: *a*, Meninges, which have become separated in process of preparation; *b*, molecular layer of gray substance; *c*, thin ganglionic layer, which under higher magnification would disclose cells of Purkinje; *d*, granule layer of gray substance; *e*, white substance.

The axis-cylinder process is nonmedullated, and passes outward into the molecular layer, where it divides into two T-shaped branches which run parallel to the free surface and terminate in blunt, unbranched ends. The second type of cell in the granule layer is called the *large granule cell.* The granule cells are less numerous than the last named, but are nearly twice as large. They are also multipolar, and send richly branching, dendritic processes into the molecular layer, and from their opposite ends numerous nerve processes, which ramify through the granule layer. The **nerve-fibers** in the granule layer are quite numerous, and are of the medullated variety, being either continuations of the fibers of the white substance beneath or branches from the ganglionic cells of Purkinje, the next layer external.

The middle layer of gray matter—the *layer of Purkinje's cells,* or the *ganglionic layer*—consists of a single row of very large ganglion cells, situated at the outer boundary of the granule layer. These cells are pear-shaped, the base being outward. From the base project two dendritic branches, which branch and rebranch until the most complex and extensive of arborizations is produced, reaching through the molecular layer. The axis-cylinder process arises from the opposite or inner pole of the cell, quickly becomes medullated, and passes into the granule layer, where it sends off a few collateral branches before passing into the white matter.

The **molecular layer** is the most external of the gray layers, and contains many multipolar ganglion cells, the dendritic processes of Purkinje's cells and some nerve-fibers.

The **ganglion cells** send a few dendritic processes toward the surface, their axis-cylinder processes running parallel with the surface and sending branches down to a point near the cells of Purkinje, where they branch to form a basket-shaped network which envelops the cell and the beginning nerve-fiber of Purkinje. These cells are called the **basket cells.**

The **nerve-fibers** are mostly the terminations of some of the medullated nerves from the white substance which have traversed the granular layer and soon lose their medullary sheath and end in free branches between the dendritic processes of the cells of Purkinje.

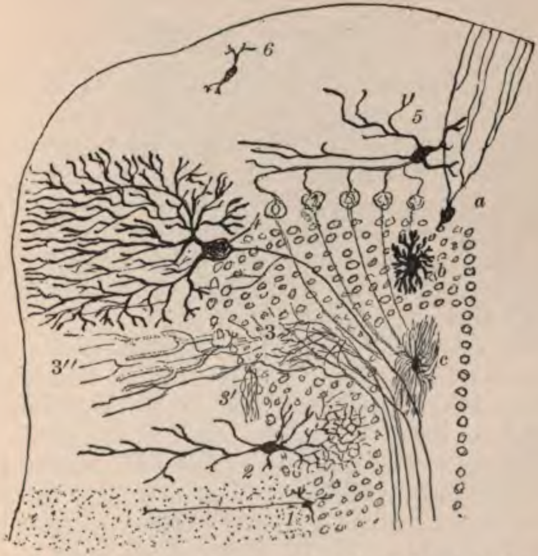

Fig. 89.—Scheme of the cerebellum cortex (after Stohr): 1, Small granule cells; 2, large granule cells; 3, plexus of nerve-fibers, 3′, horizontal bundles; 3″, fibers of the molecular layer; 4, cells of Purkinje; 5, basket cells; 6, small cortical cells; *a*, glia cells of the molecular layer; *b*, mossy cell, resembling a glia cell; *c*, spider cell.

Two principal types of **glia cells** occur in the gray matter of the cerebellum.

The first type lies between the granule layer and the molecular layer. These cells have small cell-bodies, and send but very few short processes downward, nearly all of their processes extending outward as nearly straight and but few branching fibers.

The second type of cell is of the mossy type, and occurs throughout the gray substance.

THE CEREBRUM.

The **cerebrum,** like the cerebellum, contains a gray and a white substance, with the gray external.

The gray matter may be divided into five more or less distinct layers which merge into one another without any clear boundary line. Named from without inward they are the *molecular layer,* the *layer of small pyramidal cells,* the *layer of large pyramidal cells,* the *layer of irregular or polymorphous cells,* and the *layer of spindle and pyramidal cells.*

The **molecular layer** contains numerous dendritic processes from the pyramidal cells in the next two layers; interlacing medullated nerve-fibers which run parallel to the surface; cells of Cajal, and glia cells.

The **cells of Cajal** are irregular cells occurring near the outer surface of the molecular layer. From their lateral edges a number of fine processes extend parallel to the surface, the upper ones sending small branches toward the surface. From the lower aspect of the cell one or more processes extend down into the deeper layers. The exact nature of these cells is not known, but it seems probable that they are of a neuroglia type. The glia cells are numerous, the mossy type predominating.

The **layer of small pyramidal cells** contains numerous pyramidal cells which, upon section, appear as tall, narrow triangles, with their apices toward the surface. From the apex of each cell a dendritic process extends into the molecular layer, giving off many lateral branches on the way. Other dendritic processes occasionally extend from the sides of the cells. From the center of the base the axis-cylinder process arises, and after acquiring a medullary sheath, usually passes down to the white substance, but occasionally turns and enters the molecular layer. These cells are of small size, measuring only about 10 to 12 microns ($\frac{1}{2500}$ of an inch).

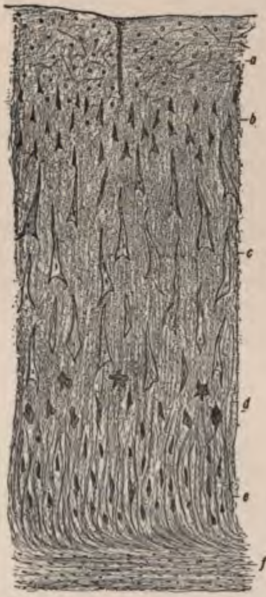

Fig. 90.—Cerebrum: *a*, Molecular layer; *b*, layer of small pyramidal cells; *c*, layer of large pyramidal cells; *d*, layer of polymorphous cells; *e*, layer of radial nerve-fibers and irregular cells; *f*, beginning of white substance.

The **layer of large pyramidal cells** differs from the preceding only in the fact that the cells are much larger (25 microns, or $\frac{1}{1000}$ of an inch), and the axis-cylinder fibers always pass to the white substance (none of them being distributed to the molecular layer), giving off collateral branches on the way.

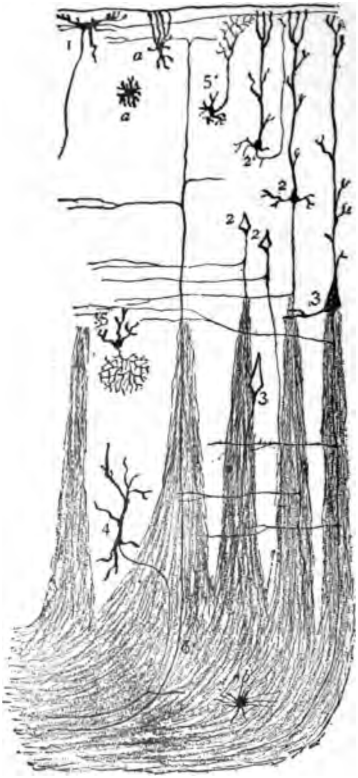

Fig. 91.—Scheme of the cerebral cortex, after Stöhr: 1, Cell of Cajal; 2, 2, 2, 2, small pyramidal cells; 3, 3, large pyramidal cells; 4, polymorphous cells; 5, 5', cells of the second type; 6, nerve-fibers ending in the superficial zone; *a*, *a*, mossy cells; *b*, spider cell (glia cell). Ependymal cells not represented.

The **layer of irregular** or **polymorphous cells** is characterized by the presence of polygonal cells, from which one or two irregular dendritic processes project and branch a few times. The axis-cylinder fibers acquire a medullary sheath, send off a few collaterals, and pass into the white substance, where they may branch, the two divisions proceeding in opposite directions at right angles to the descending fibers, forming a T-shaped fiber.

The **layer of spindle** and **pyramidal cells** contains, besides scattered pyramidal cells similar to those of the second layer and oval ganglion cells, large numbers of medullated nerve-fibers in transit from the white substance to the layer above.

The oval cells resemble the small pyramidal cells, with the exception of their bases, which taper downward, giving the cell a more fusiform outline.

The **white substance** consists of medullated nerve-fibers, devoid of neurilemma, held together by neuroglia tissue similar in structure to the white substance of the cerebellum.

Small projections extend down into the cerebral and cerebellar substance from the pia mater, conducting blood-vessels, which branch and, acquiring a covering of neuroglia tissue, become distributed as a capillary network throughout the organ.

PITUITARY BODY.

The **pituitary body,** or **hypophysis cerebri,** may be classed with the ductless glands, and consists of two portions.

The **anterior portion** is the larger, and consists of gland acini, surrounded by loose fibrous tissue. The acini are lined by cuboid epithelial cells, which in many instances fill the lumen. Occasionally, **a clear, colloid** substance is found in some of the acini **resembling the** colloid substance found in the thyroid.

The **posterior portion** contains a **complexus of fine** branched nerve-fibers, multipolar **ganglion cells, blood-**vessels, and connective tissue.

THE PINEAL BODY.

The **pineal body** is a rudimentary special **sense organ,** the vestige of a more highly developed **structure in pre-**historic animals low in the scale of life. It still **persists** fairly well developed in some of the living **reptiles. It** seems probable that one of its functions was the **percep-**tion of heat. In structure it consists of **a number of acini** separated from one another by fibrous tissue **and lined** by columnar epithelium. Occasionally, **concretions of** a calcareous matter are found in the acini, **external to** them and in the brain membranes, called "**brain sand.**"

Small, discoid bodies of a starch-like nature, **present-**ing concentric striations and staining violet **with iodin** and sulphuric acid, also occur in the brain **substance** and membranes around the ventricles, and **have been** called the **corpora amylacea.**

THE SUPRARENAL BODY.

The **suprarenal body, capsule,** or the **adrenal, is** covered by a thick capsule of fibrous tissue, and divided into a cortical and a medullary portion.

The cortical portion further divides into three **layers** —the *zona glomerulosa,* the *zona fasciculata,* and the *zona reticularis.*

The **zona glomerulosa** consists of round or ovoid masses of epithelial cells. In the **zona fasciculata** the cells are arranged in long, solid, cylindrical cords. The **zona reticularis** contains branching columns of cells which are pigmented. All of the different groups of cells are separated by bands of fibrous tissue.

The **medullary portion** is composed of irregular branching cords of pigmented polyhedral cells, surrounded by vascular connective tissue, in the center of which many nonmedullated nerve-fibers and ganglion cells occur.

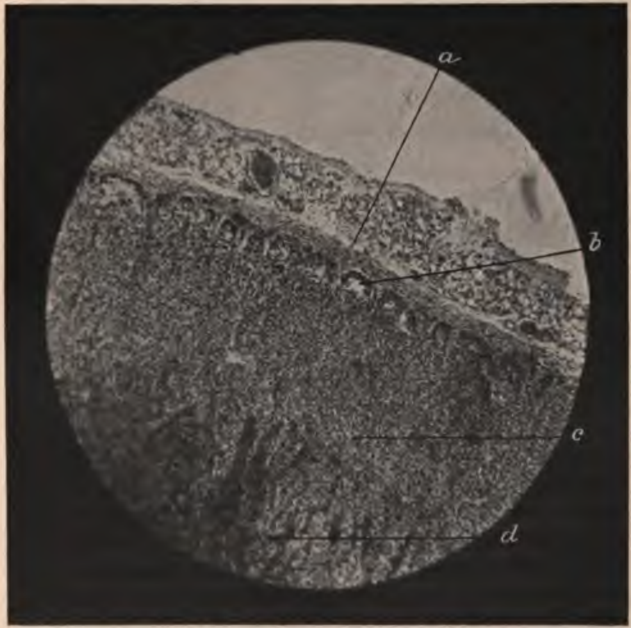

Fig. 92.—Suprarenal body: *a*, Thick capsule; *b*, groups of cells forming the zona glomerulosa; *c*, zona fasciculata; *d*, zona reticularis.

The **blood-vessels** enter through the capsule and, passing down between the masses of cells, envelop them in a capillary network. The capillaries collect in the medullary veins and make their exit at the hilum.

The *nerve supply* is unusually rich, consisting of large nonmedullated fibers, although medullated fibers and ganglion cells are not unusual.

The *lymphatics* originate in the fibrous bands of both the cortex and the medulla, and communicate with larger vessels in the capsule.

QUESTIONS FOR CHAPTER XVII.

351. What are the coverings of the spinal cord?

352. Describe the dura mater. What are the epidural spaces? the subdural spaces?

353. The subarachnoidean spaces?

354. What are the Pacchionian bodies?

355. Do blood-vessels or nerves occur in the arachnoid? Describe the structures occurring.

356. Describe the arachnoid.

357. How many layers does the pia mater represent? Describe each.

358. Of what is the substance of the cord composed?

359. Describe the gross arrangement of the gray matter.

360. Describe the anterior horn; posterior horn; gray commissure; central canal.

361. Describe the gross arrangement of the white matter.

362. Describe the anterior median fissure; the posterior median fissure; anterior columns; lateral columns; the posterior columns.

363. What is meant by secondary columns? Name the principal ones.

364. Give the location of the direct pyramidal tract; the anterior ground bundle; direct cerebellar tract; crossed pyramidal tract; descending anterolateral; mixed lateral; column of Goll and column of Burdach.

365. In which direction do the fibers run in each of the preceding tracts?

366. Which of the preceding secondary tracts are contained in the anterior columns?

367. In the lateral columns? in the posterior columns?

368. What structures constitute the gray substance?

369. Describe the nerve-cells.

370. Name the principal groups of nerve-cells in the gray matter and give their location. What is the column of Clarke?

371. What is an axon or neuraxon?

372. Give the general characteristics of the ganglion cells. What are the chromatophilic granules?

373. What are the characteristics of the cells in the posterior horns?

374. Describe the dendritic processes.

375. What is neuroglia tissue?

376. What are the glia cells? spider cells? mossy cells?

377. What is the reticular process? substantia gelatinosa Rolandi? the zona spongiosa? and the zona terminalis?

378. Describe the minute structure of the white substance. Give its blood supply.

379. Of what does the cerebellum consist? What is the arbor vitæ?

380. Name the layers of the cerebellum.

381. Describe the white substance.

382. Describe the granule layer. Describe the large and small granule cells of this layer; the nerve-fibers.

383. Describe the layer of Purkinje's cells.

384. Describe the molecular layer. What are the basket cells? Describe the nerve-fibers and glia cells of this layer.

385. Name the gross structures of the cerebrum.

386. How many layers of the gray substance? Name each.

387. Describe the molecular layer. What are the cells of Cajal?

388. Describe the layer of small pyramidal cells.

389. Describe the layer of large pyramidal cells.

390. Describe the layer of polymorphous cells.

391. Describe the layer of spindle and pyramidal cells.

392. Describe the white substance; blood supply.

393. Name the two portions of the pituitary body. Describe each.

394. What is the pineal body. Describe its structure.

395. What is brain sand? corpora amylacea?

396. Describe the gross arrangement of the suprarenal capsule.

397. What are the three layers of the cortical portion? Describe each.

398. Describe the medullary portion.

399. Describe the blood supply, nerve supply, and lymphatics of this organ.

CHAPTER XVIII.

TECHNIC.

THE preparation of histologic objects for microscopic examination requires a varying amount of manipulation, which is referred to in general as **technic.** A few of the simpler structures, such as bits of serous membrane, blood, or isolated epithelial cells scraped from free surfaces, may be placed upon a slide with a drop of salt solution and examined at once. Other structures, as muscle, white fibrous tissue, yellow elastic tissue, or nerve-fibers, may be prepared for a preliminary examination by the process known as **teasing.** This consists in gently tearing small bits of the tissue as finely as possible by means of "needles," so as to produce ragged, thin edges. An ordinary sewing needle sunk a quarter of an inch into the handle of a penholder answers perfectly for this purpose. The teasing should be carried on in a drop of physiologic salt solution (made by dissolving 6 to 9 grams of NaCl in 1000 c.c. of water) or of glycerin. Occasionally, previous to teasing, bits of tissue are subjected to the action of one of the "dissociating" fluids, just enough of the solution being used to cover the tissue. Several days are required for the structural elements to soften so as to be readily separated from one another, and during this time the fluid should be protected from evaporation. Two of the best of the fluids which are used for this purpose are 33% alcohol (1 part alcohol to 2 parts water), or chromic acid, $\frac{1}{5}$ to $\frac{1}{2}$ gram to 1000 c.c. of water. In order, however, to obtain more satisfactory preparations, thin sections of the various tissues must be obtained, and changes in the form and arrangement of the more minute elements must be guarded against.

FIXATION.

Substances that rapidly kill tissues and prevent further structure change are called *fixatives*. Of these there are a number which are more or less desirable according to the special tissue at hand or the end in view.

Alcohol is used extensively, but more for dehydrating and preserving tissue than as a fixative. Absolute alcohol will fix small pieces of tissue (0.5 cm. cube) almost instantly, and is satisfactory when the finer nuclear structure is not especially sought. In gradually increasing strengths of 50, 60, 70, 85, 95%, and absolute, successively from twenty-four to forty-eight hours each, it gives fair results for ordinary work. Some shrinkage of the tissues will occur, but, on the other hand, good results may be subsequently obtained with any of the stains. For preserving specimens 70% alcohol answers admirably.

Chromic acid, in strengths varying from 0.1% to 1%, fixes well in two or three days, but tissues fixed in it are liable not to stain well, and if strong solutions are employed, artefacts are often produced.

Potassium bichromate and **ammonium bichromate,** in 2% or 3% aqueous solution, penetrate well, but do not preserve the detail of cell structure so well as many other fixatives. A month or more is required to complete the hardening, when the tissues should be washed twenty-four hours in running water and preserved in 70% alcohol.

Müller's fluid consists of—

Potassium bichromate	2.5 gm.
Sodium sulphate	1 "
Water	100 c.c.

This solution will keep indefinitely, and is valuable for fixing large masses of tissue, especially of the central nervous system. It should be used in large amounts (at least 15 to 20 times as large a volume as the tissue to be fixed) and frequently changed. A good plan is to change the solution daily for four days, and then weekly for about six weeks, when the specimen should be washed in running water overnight and kept in 70% alcohol (in the dark), which is replenished whenever it becomes discolored. Tissues fixed in Müller's fluid will, as a rule, stain better with some one of the logwood stains than with the carmins.

Formaldehyd is sold as a saturated 40% solution, and in this form is sometimes called "formol" or "formalin." It is best kept in tightly stoppered bottles and diluted or mixed with other reagents only as wanted for use. It forms an excellent fixative for most all tissues when diluted with either water or 95% alcohol to a strength of from 5% to 10%. It fixes tissues in from one-half to twelve hours, and permits the use of any of the stains subsequently.

Orth's solution consists of—

Müller's fluid	90 c.c.
Formalin	10 "

Müller's fluid can be kept in quantity and the formalin added at the time required. This solution fixes pieces of tissue two centimeters thick in twenty-four hours, giving all the advantages of both formalin and bichromate fixatives. After fixation the tissues should be washed in running water for twelve hours and placed in 70% alcohol.

Flemming's solution is composed of—

Osmic acid (2% solution)	4 c.c.
Chromic acid (1% solution) . . .	15 "
Acetic acid (glacial)	1 "

These proportions are sometimes varied slightly for special purposes.

The ingredients should be kept separately and mixed *immediately* before using. The osmic acid should be kept in a brown, glass-stoppered bottle, and protected from the light. Tissues should be placed in this solution immediately while the cells are still living, and small insects or newts may be dropped in directly while alive. After twenty-four hours the specimen should be washed for two hours and placed in 70% alcohol. This method is the best for showing the finer nuclear structures and for the study of karyokinesis.

Mercuric chlorid has been employed as a fixative in a number of combinations. As reliable a formula as any is Heidenhain's:

Sodium chlorid	7.5 gm.
Water	1000 c. c.

Dissolve in this, with the aid of heat, mercuric chlorid to the point of saturation and allow the solution to cool. Upon cooling fine crystals of the mercuric chlorid will be deposited. This solution will fix pieces of tissue one centimeter thick in from two to twelve hours. The specimens should then either be washed for twenty-four hours in running water or, better, placed for twelve hours in 70% alcohol that has been colored dark brown by the addition of tincture of iodin, to eliminate crystals of mercuric chlorid which will be deposited in the tissue. This should be followed by 70% alcohol until the specimen is wanted for use. Occasionally, however, the iodin solution is not used until the specimens have been cut into sections, when a relatively short immersion suffices to remove any crystals of the $HgCl_2$.

Mercuric chlorid-acetic acid does well as a fixative, and is made by adding 5% of glacial acetic acid to a saturated aqueous solution of mercuric chlorid. Small pieces of tissue fix well in three hours, and should be transferred to 35% and gradually ascending strengths of alcohol. Iodin may be added to the alcohol to dissolve the crystals of mercuric chlorid, or sections may be cut first, and then immersed in the iodized alcohol previous to staining.

Zenker's fluid combines the good points of the chrome and mercuric fixatives. Its formula is as follows:

Potassium bichromate	2.5	gm.
Sodium sulphate	1	"
Mercuric chlorid	5	"
Glacial acetic acid	5	c.c.
Water	100	"

Dissolve the first three ingredients in the water, and add the acetic acid only at the time the solution is wanted for use. Tissues are fixed from four to twenty-four hours, washed twelve to twenty-four hours in running water, and dehydrated in ascending strengths of alcohol. Crystals of mercuric chlorid may be removed as in the two previous solutions.

DECALCIFICATION.

Before sufficiently thin sections of bone or other calcareous tissue can be cut it becomes necessary first to dissolve out the calcium salts. For this purpose a number of solutions are in vogue known as *decalcifying solutions*. As a rule, small pieces of the bone should be used (not more than 0.5 cm. in thickness).

Picric acid, as a saturated aqueous solution, requires weeks, but is very satisfactory. A few crystals should be added from time to time to insure complete saturation, until all the lime-salts have been dissolved. This may be ascertained by passing a fine needle through the specimen. When it is completely decalcified, the needle will encounter no gritty particles. The specimen should then be placed in 70% alcohol containing an excess of lithium carbonate for twenty-four hours, and then frequently changed to fresh alcohol until its color remains untinged.

Chromic and nitric acids also give good results, and are a trifle more rapid in their action. Place small pieces of bone in—

Chromic acid	3 gm.
Water	1000 c.c.

for six days, changing the solution on the third day. Then transfer it to fresh solution, to which has been added 2% of nitric acid, in which mixture it remains until decalcified, when it is washed for forty-eight hours in running water and transferred to 70% alcohol.

The **nitric acid phloroglucin** method is very rapid (eight to twelve hours) and one of the best:

Phloroglucin	1 gm.
Nitric acid	10 c.c.
Dissolve by heating and add water .	100 "

As soon as the lime-salts are all dissolved, transfer the tissues to 70% alcohol, which should be renewed several times. Specimens decalcified by either of these methods stain well in "bulk," and should be cut into very thin sections for examination.

INJECTION.

In order to study the distribution of the smaller blood-vessels or lymphatics, recourse is had to a number of processes of filling them with some more or less opaque substance. The processes are collectively known as "injections," and the substances used as "injection masses." These may be either introduced into the aorta or through the left ventricle, in which case the entire animal may be used; or separate organs are taken and the mass introduced through the afferent artery.

The two most satisfactory masses are known as the "carmin-gelatin" and the "Berlin blue."

The **carmin-gelatin mass** is prepared as follows:

Carmin	3 gm.
Strong ammonia	6 c.c.
Water	30 "

Rub the carmin and ammonia together in a mortar, and then add the water. Allow it to stand for a couple of hours, and transfer to a bottle of very clear white glass. Now add glacial acetic acid carefully, drop by drop, from a buret or dropper, shaking carefully after each addition. Continue adding the acid until the solution is *exactly* neutralized, which is shown by the solution changing from a deep purplish red color to a brilliant red. At this time the carmin is precipitated as an extremely fine powder, so fine that it should show no granules when examined with an ordinary high-power objective.

While the foregoing has been standing, the gelatin should have been carefully melted in a porcelain evaporating dish, and the carmin solution added little by little, with thorough stirring after each addition.

The gelatin is prepared by taking

French gelatin (Coignet's)	7 gm.
Water	50 c.c.

Allow the gelatin to soak in the water in an evaporating dish for four or five hours before it is required for melting.

As soon as the gelatin is mixed with the carmin it is ready for use; but if it is placed in a bottle and covered with a little methyl alcohol, it can be preserved for a long time, and be ready for use by simply pouring off the alcohol and heating. It is always advisable to filter the melted mass through muslin immediately before using.

Berlin blue mass is simpler to prepare, and gives very pleasing effects when sections are counterstained with some of the carmin solutions. The following is a good formula for its preparation:

Berlin blue (Grubler)	1 gm.
Water	200 c.c.

As soon as the injection is finished, tie a ligature around the artery and place the whole organ into alcohol or Müller's fluid.

The injection of the mass into the arteries is best accomplished by means of a syringe of about 50 c.c. capacity and fitted with interchangeable cannulas of various sizes and a stopcock. By this means a little practice will enable one to estimate the exact amount of pressure required to rapidly force the solution into the vessels while not using sufficient force to rupture the delicate capillaries and cause an extravasation.

Before starting to inject an animal or organ it is usually best to allow the blood to flow out as much as possible; and when the gelatin mass is to be used, the entire animal or organ should be kept under warm water, to prevent a too rapid hardening of the gelatin.

When tissues have been injected, they are hardened and cut into sections in the same way as ordinary specimens.

SECTIONING.

As, almost without exception, histologic specimens are examined by transmitted light, the portion under examination must be extremely thin to allow of ready passage of light, as well as to avoid an apparent confusion of structural detail which would result from the superposition of several layers of cells. Several methods are in use to obtain the requisite thinness, but in any case (excepting frozen sections) the specimen, after being fixed or decalcified, must be **thoroughly dehydrated** and sufficiently **hardened** to cut well without either being brittle or easily torn. Alcohol in gradually increasing strengths is used for this purpose, allowing the specimens to remain for from twelve to forty-eight hours in 70 %, 85 %, and 95 %, and absolute alcohol. Specimens are occasionally sectioned by hand, with a sharp razor, after removal from the absolute alcohol. If the specimen is small and not easily held by the fingers, it may be clamped between two pieces of pith or in a slit in a piece of alcohol-hardened liver or, still better, placed upon a small block or in a little pill-box, into which melted paraffin is poured and allowed to cool. The mixture of paraffin 2 or 3 parts, tallow 1 part, as recommended by Piersol, will be found superior to the pure paraffin. In either case the specimen should be held in the left hand, which rests either upon a table or against the chest, and the razor, wet with alcohol, is held in the right hand, with the edge toward the body, and made to pass over the specimen from point to heel. The endeavor should be to obtain sections as thin as possible rather than of great size. As soon as the sections are made, if they are embedded in paraffin, they should be placed in a small dish containing turpentine or xylol, which will dissolve the paraffin, and then, if they require further staining, into absolute, followed by weaker, alcohol. If the block of tissue has not been embedded in the paraffin, the sections may be placed directly in a dish of 85% alcohol or in water.

The method of cutting sections free-hand requires considerable practice, and is even then of value in but few instances. The best results can be obtained only by one of the many forms of **microtomes**, or mechanical knives, which are manufactured. These will correspond to one of two types:

1. Those in which, while cutting, the object is stationary and the knife moves.
2. Those in which, during the cutting, the knife is stationary, while the object is moved against it.

As a general rule, instruments of the first class are better adapted to cutting frozen and celloidin embedded specimens, and those of the second class do better with paraffin specimens. However, several of the best instruments of either class may be made to do excellent work with any of the embedding methods.

When thin sections of delicate tissue are to be made, the tissue must first be thoroughly infiltrated with some substance that will offer no material resistance to the cutting and which at the same time will fill all spaces between the cells, and hold them in their normal relative positions (interstitial embedding). There are three principal ways of accomplishing this, known respectively as the celloidin, paraffin, and freezing.

CELLOIDIN EMBEDDING.

The specimen after having been fixed and thoroughly dehydrated and hardened, is placed for from twenty-four to forty-eight hours in equal parts of absolute alcohol and ether; then for twenty-four hours in "thin celloidin," made by dissolving:

Celloidin (or good gun-cotton) . .	3 gm.
Ether and absolute alcohol . .	āā 100 c.c.

Transfer specimen for twenty-four hours or, if it be large or dense, forty-eight hours to "thick celloidin":

Celloidin (or good gun-cotton) . .	6 gm.
Absolute alcohol and ether . .	āā 100 c.c.

From the thick celloidin it should be placed with its best surface uppermost upon a small block of wood or ground glass around the edges of which several turns of paper have been wrapped, making a sort of box with paper sides, the specimen resting upon the wooden or glass bottom.

Thick celloidin is now poured in until the specimen is covered, and the whole thing is set aside until the celloidin "sets," or becomes thickened sufficiently to prevent the specimen changing its position. The length of time which this will take will depend upon the size of the specimen, the depth of the celloidin, the temperature of the room, etc., so that no definite time can be given. The block should, however, be watched; for if allowed to dry too much in the open air, the celloidin will become hard and shrink, distorting the specimen. As soon as it is sufficiently set, it should be immersed in 85% alcohol or chloroform, where it will slowly (twenty-four hours) harden until it becomes clear and transparent and almost the consistence of soft cartilage. The specimen may be kept in the alcohol or chloroform at this stage for days, if it is not convenient to proceed with the further operation of preparing the sections. When the sections are to be cut, the block is taken from the alcohol or chloroform, and the paper carefully removed; any excess of celloidin is carefully trimmed off with a knife, leaving only a thin margin around the top edges of the specimen, but not removing too much from around the base, lest it separate from the block during the subsequent operations. The block is then clamped in the microtome in such a manner that the long diameter of the specimen is parallel to the direction of motion of the knife, and the upper surface just escapes the knife edge as it passes over. The knife is then set obliquely to the specimen, so that as much of the edge as possible will pass through the specimen in cutting a section. The specimen is raised slightly by means of the micrometer screw beneath; the knife is then flooded with 85 % alcohol and drawn quickly and smoothly across the specimen. This is repeated several times until an even surface is obtained and the sections removed pass through sufficient of the specimen, when the specimen is raised a known and uniform distance at each cut, and the sections are transferred to clean 85 % alcohol as fast as they are produced. As many sections as will be desired should be cut, as they may be kept indefinitely in 85 % alcohol until wanted; whereas, in the block they are liable to soften if left in the alcohol, and if allowed to dry will spoil entirely. Sections prepared in this way can not be cut so thin as when paraffin is used, a fairly satisfactory average being from 15 μ to 20 μ in thickness.

PARAFFIN EMBEDDING.

Pieces of tissue which have been fixed and dehydrated are passed from absolute alcohol into chloroform, xylol, turpentine, or equal parts of alcohol and cedar oil, and allowed to remain there until they become translucent. The length of time necessary will vary from one to twelve hours, according to the density and size of the tissue.

If chloroform is chosen, the tissue is next placed for twelve hours in a saturated solution of paraffin in chloroform. If cedar oil and alcohol have been used for the previous step, the tissue is put into pure cedar oil for twelve hours. If xylol or turpentine has been chosen, or in the previous two cases, after the immersion in the solution of paraffin and chloroform or pure cedar oil, the tissues are placed in melted paraffin whose melting-point is 50° C., and kept at a temperature of from 51° to 52° C., in an oven, for from two to eight hours, according to the size and density of the specimen. By this time the molten paraffin will have penetrated every portion of the tissue. The specimen is now removed with a pair of forceps (which have been slightly warmed to prevent the paraffin from hardening about them) and placed upon a plate of glass or metal, quickly surrounded by two L-shaped pieces of metal arranged so as to form a square, and the square so formed filled with molten paraffin. The paraffin is allowed to cool for a moment until a thin skin forms over the top, when the whole thing is plunged into cold water in order to solidify the mass as quickly as possible. When thoroughly cold, the block of paraffin containing the tissue at the lower end is separated from its metal casing and carefully dried. Then the block is cut away from the sides of the specimen, leaving a margin of only about 1 mm. of paraffin around each side, but being careful that the opposite outer edges of the margin are parallel. The block is now clamped in the microtome with the longest diameter of the specimen transversely to the path of the knife. The knife must be so placed that its edge is at right angles to its path and that it will pass squarely through the specimen, and not obliquely, as is the case in cutting celloidin. The sections are cut with the knife dry, and may be removed one at a time as they are cut or allowed to adhere, the front edge of one to the hind edge of the preceding, as they are cut, so as to form a "ribbon."

Only as many sections should be cut as will be needed at once, as the embedded block will keep indefinitely and can always be cut from at any subsequent time. If the tissue is tough and the sections are not too thin, they may be placed at once in xylol or turpentine, to dissolve out the paraffin, and thence in absolute alcohol if they are to be stained; or if already stained in bulk, they may be mounted in Canada balsam. If the sections are fragile, they must be mounted on glass slides. The slides having been thoroughly cleaned, a very thin layer of Mayer's albumin is spread upon one side, either with a camel's-hair brush or with the fingers, and allowed to dry. The Mayer's albumin is made by mixing—

White of egg	50 c.c.
Glycerin	50 "
Sodium salicylate	1 gm.

shaking very thoroughly with a few pieces of broken glass (to hasten the solution of the egg), and filtering through coarse filter-paper. This filtration may require weeks, but the resulting solution, if tightly stoppered, will keep good for a year or more. As soon as the sections are cut, they are picked up with a needle or brush or fine forceps and carefully floated upon warm water (40° C.), when they will at once flatten out and become perfectly smooth. The edge of one of the albuminized slides is carefully dipped into the water and the section carefully floated up into place by means of a needle. The slide is removed, the excess of water drained off, and the slide placed on top of the oven or in an incubator (37° C.) for several hours, or the slide and sections may be allowed to dry and may then be immersed in equal parts of alcohol and ether for an hour, which will coagulate the albumin and fix the section fast to the slide. The slide is now immersed in xylol, turpentine, or benzol for a few minutes to dissolve off the paraffin. After this it is placed in absolute alcohol, after which it may be stained in whatever way desired.

FREEZING.

This is a very rapid method of preparing sections. The tissues may either have been fixed or may be perfectly fresh. If fresh, they had best be fixed for an hour or so in 10 % of formalin in water. If they have already been fixed, they should be placed for an hour or more in water, in order to extract the alcohol, which would greatly retard the freezing. They are next placed in a thin solution of cane-sugar and gum arabic (2 gm. to 100 c.c.) in water, to which a small piece of camphor or thymol has been added to prevent the growth of mold, and allowed to remain for three or four hours.

While a little more troublesome to make, the following solution has several advantages over the plain gum and sugar:

Two stock solutions are made and kept on hand.

(*a*)

Cane-sugar	28.5 gm.
Water	30 c.c.

Boil, and while hot saturate with boracic acid; cool and filter.

(*b*)

Gum acacia	45.6 gm.
Water (cold)	2400 c.c.

When dissolved, add boracic acid to saturation by boiling; cool and filter.

For use:

Solution *a*	4 parts.
Solution *b*	5 "
Water	9 "

Boil, and saturate with boracic acid; cool and filter through muslin. Tissues may be kept for an indefinite time in this solution, and be ready to cut immediately.

The pieces of tissue are then removed, placed upon the drum of the freezing microtome, a small quantity of gum solution added, and the ether spray or liquefied carbon dioxide turned on gradually until the whole mass begins to congeal. As soon as it becomes solid and of a dull luster, and before it turns hard and white, the sections should be rapidly cut, with the knife-edge at right angles to the direction of movement. If the specimen chance to have been frozen too hard, it should be allowed to soften slightly for a moment before cutting the section, as if this is not done the sections may be imperfect and the knife-edge damaged. As soon as the sections are cut they should be placed in water, in order to expand as well as to dissolve out the gum. They may subsequently be stained by any one of the various methods.

STAINING.

Thin sections of tissue being very transparent and often highly and evenly refractive to light, it becomes advantageous to stain them, so as to produce a stronger and more easily studied image. Again, as different elements of tissue and cells are of varying chemic composition, they are found to be differently affected by various stains, so that by a suitable selection of stains contrast effects may be produced which aid very materially in distinguishing and studying closely associated details. The number of methods of staining tissues which have been suggested and used is enormous. At present only one or two of the simpler but most generally useful can be given.

Borax carmin is one of the most reliable and most easily handled of the stains. Grenacher's formula is as follows :

Carmin (No. 40)	1.25	gm.
Borax	2	"
Water	50	"
Alcohol (70%)	50	"

The borax, carmin, and hot water are rubbed thoroughly in a mortar and allowed to cool. The alcohol is then added, and the whole allowed to stand for two or three weeks, and then filtered. This preparation is the stain best adapted to *bulk staining*, for which purpose the previously fixed and hardened pieces of tissue are immersed for three days. From this they are transferred directly into—

Hydrochloric acid (10%)	4	c.c.
Alcohol (70%)	100	"

where they should remain for forty-eight hours. When removed, the specimens should be of a bright, deep-red color. They are next placed in 85 %, 95 %, and absolute alcohol for twenty-four hours each, after which they are ready for the solution immediately preceding the infiltration and embedding.

If sections are to be stained, they should be placed in the fluid for half an hour, then in—

Hydrochloric acid (pure)	5 c.c.
Alcohol (70 %)	100 "

for from five to ten minutes, from which they should go into absolute alcohol and then into the clearing mixture. The borax carmin stains all parts of the tissue almost equally of a dull-red color, which would readily wash out. When, however, it is treated with the dilute HCl, the excess of stain is dissolved out, the nuclei remain more deeply stained than the rest of the tissue, and the stain is fixed permanently. A pleasing contrast staining results if a few crystals of **picric acid** are dissolved in the alcohol and used after the stain as well as in the final clearing medium. In this case the nuclei will remain a deep-red, whereas the cell-bodies and intercellular substances will assume a bright canary yellow.

Mayer's paracarmin is made as follows:

Carmimic acid	1	gm.
Aluminum chlorid	0.5	"
Calcium chlorid	4	"
Alcohol (70 %)	100	c.c.

Dissolve, warming if necessary; cool and filter.

This solution stains splendidly in bulk, and will penetrate even better than borax carmin; hence it can be used for large specimens. Sections stain in a few minutes, and need only be rinsed in 70 % alcohol before being dehydrated, cleared, and mounted. For bulk staining the specimen should remain in the stain from one to ten days, according to its size and permeability, when it can be washed in 70 % alcohol, dehydrated and imbedded. Paracarmin rarely overstains either tissues or sections; but if such a condition should occur, the excess may be removed by adding 0.5 % aluminum chlorid or 2.5 % glacial acetic acid to the 70 % alcohol when washing the specimens. Care should be taken not to place objects in the stain which have an alkaline reaction. Any other failure with this stain can usually be traced to a poor quality of carmimic acid.

Hematoxylin is of equal value and as extensively used. *Delafield's* formula, while being a trifle more complex than some others, is still the most satisfactory:

Hematoxylin	4 gm.
Alcohol (absolute)	25 c.c.

Dissolve and add

Ammonia alum	52 gm.
Water	400 c.c.

Allow the mixture to stand in the light for a week and then add

Glycerin	100 c.c.
Methyl alcohol	100 "

The whole mixture should be kept in the sunlight as much as possible for two weeks longer, when it is ready for use; it will usually keep well for a year. If it becomes too strong and stains too rapidly, small quantities may be diluted to any requisite amount with distilled water.

For *bulk staining* the stain is diluted until it is quite transparent, and pieces of fixed tissue are immersed in it until they become *dark* blue. As the stain varies very much in power from time to time, no definite length of time can be given. Ordinarily, however, the stain should be diluted until of such strength as will stain blocks well in twenty-four hours. Care should be taken to avoid overstaining, but a trial or two will suffice to determine the dilution necessary. From the hematoxylin solution the tissues should be placed in an abundance of water, where they should remain with occasional agitation for forty-eight hours. From this they are transferred to increasing strengths of alcohol until absolute, embedded, and cut.

Sections are placed in the solution for from three to fifteen minutes, according to the strength of the stain; washed well in water from three to five minutes, then in 95% alcohol, then absolute alcohol, and next in the clearing medium.

Mayer's hemalum can be used at once, and stains quite well in bulk, but does not keep so well as Delafield's hematoxylin.

(*a*)

Hematein	1 gm.
Alcohol (95%)	50 c.c.

Dissolve by heating.

(*b*)

Alum	50 gm.
Water	1000 c.c.

Pour *a* into *b*; filter, and add a crystal or two of thymol to prevent the growth of moulds. Sections after staining should be washed in distilled water, and may be counterstained.

For bulk staining the solution should be diluted with distilled water and the tissue immersed for twenty-four hours or more and washed in distilled water. It does not overstain.

Acid hematoxylin is likewise an excellent stain and keeps well. Kulschitsky's formula is as follows:

Hematoxylin (crystals)	1 gm.
Alcohol (absolute)	20 c.c.

Dissolve and add

Acetic acid (2%)	100 c.c.

Sections should be stained in this fluid for from five to fifteen minutes, washed in water, and placed in a saturated solution of lithium carbonate until they assume a fine deep blue color, when they may be dehydrated, cleared, and mounted.

Logwood and eosin staining, when combined, make one of the most pleasing combinations of stains. By this method nuclei are stained deep blue, while the cell-bodies and intercellular substances become a fine pink to red, according to the depth of the eosin staining. At the same time red blood-corpuscles assume a characteristic coppery-red tinge, which makes them very easily recognized. After the specimen has been stained in the hematoxylin (by either of the above methods) and washed in water, it is placed for two minutes in—

Eosin (yellowish)	0.5 gm.
Alcohol (70%)	100 c.c.

after which it is dehydrated, cleared, and mounted.

DEHYDRATION OF SECTIONS.

All sections which are to be finally mounted in Canada balsam must, after staining, be dehydrated. If this is not thoroughly accomplished, any trace of moisture remaining will precipitate the balsam, producing a cloudy mount. If some one of the clearing agents is used, such as clove oil or creasote, 95% alcohol may be used to dehydrate the specimen, otherwise absolute alcohol must be used.

CLEARING.

After the specimens have been stained and dehydrated they are subjected to the action of a clearing agent, the purpose of which is to remove the alcohol used in dehydrating, to render the specimen transparent, to act as a preservative, and to afford a substance which will be readily miscible with the Canada balsam.

Of these clearing agents there are many: Xylol, turpentine, creasote, clove oil, cedar oil, oil of bergamot, and, in fact, nearly all the essential oils may be used.

Of these, **creasote** (which must be the best German beechwood variety) is most satisfactory for celloidin sections, as the celloidin is not attacked by it as it would be by clove oil. Creasote also clears well from 95% alcohol.

Xylol, either pure or with the addition of half its weight of crystallized carbolic acid, makes an excellent clearing agent for paraffin sections, but requires very thorough dehydration.

Oil of cloves is reliable and has the quality of dissolving celloidin, which may be either desirable or not according to the case in hand.

MOUNTING.

If the sections are unattached to the slide, they should be lifted from the clearing agent by means of a section-lifter, which is gently slid under the section and lifted out of the fluid, the section meanwhile being held in place by means of a needle. The section is then gently slid off the lifter on to the center of a clean glass slide and the excess of clearing agent carefully removed by means of a clean piece of filter-paper. A drop of Canada balsam is placed on the center of the section and covered by a cover-glass, care being taken that just enough balsam is used to fill all the space between the cover-glass and slide, and at the same time to avoid air-bubbles. The paper-filtered balsam, which comes in collapsible tubes, or xylol balsam will be found to be the best agents for mounting specimens. The slide should be labeled at once, and may be examined or put away in a horizontal position for a few days, by which time the balsam will be quite well set so as to retain the cover-glass in position.

Damar may be used in the place of Canada balsam. It has the property of not rendering the specimens quite so transparent, which in some cases will show more detail and is advantageous. It is used in the same manner as the balsam, and can be bought ready prepared; or it may be made by dissolving the gum in equal parts of benzine and oil of turpentine until a thick consistency is reached.

Farrant's solution also makes a convenient mounting medium for specimens which have not been dehydrated, as blood-cells fixed in Hayem's solution, or sections stained in picrocarmin before they are placed in the final alcohol and clearing bath.

Glycerin	50 c.c.
Water	50 "
Gum arabic	50 gm.
Arsenous acid	1 "

Dissolve the arsenous acid in the water, then add the gum, and allow it to stand for several days. Next add the glycerin; mix thoroughly, and filter through cloth. It is used in the same manner as balsam, but only with objects which have previously been in water or an aqueous solution.

TABULAR SCHEME OF PREPARATION OF TISSUE TO BE STAINED IN BULK.

1. Fix in one of the fixing solutions.
2. Wash in water, according to fixative used.

Borax Carmin.		*Hematoxylin.*	
3. Borax carmin	3 days.	3. Delafield's hematoxylin	24 hours.
4. Acid alcohol	2 "	4. Water	48 "

Borax Carmin.

5. Alcohol (85%) . . 24 hours.
6. Alcohol (95%) . . 48 "
7. Alcohol (absolute) 48 "

If Embedded in Paraffin.

a 1. Xylol, turpentine, or chloroform until translucent—one to twelve hours. If chloroform is used, next to saturated solution of paraffin in chloroform twelve hours.
a 2. Melted paraffin, two to eight hours.
a 3. Cast block.
a 4. Cut sections.
a 5. Fix to slide with Mayer's albumin.
a 6. Dissolve off paraffin, and clear with xylol.
a 7. Mount with drop of Canada balsam.

Hematoxylin.

5. Alcohol (70%) . . 24 hours.
6. Alcohol (85%) . . 24 "
7. Alcohol (95%) . . 24 "
8. Alcohol (absolute) 24 "

If Embedded in Celloidin.

a 1. Alcohol and ether . . 24 to 48 hours.
a 2. Thin celloidin . 24 "
a 3. Thick celloidin 48 "
a 4. Block, and allow to set.
a 5. Chloroform or 85% alcohol . 24 hours.
a 6. Cut section.
a 7. Place sections in absolute alcohol two minutes.
a 8. Creasote, or other fixative, three minutes.
a 9. Place on slide with section-lifter and remove excess of solution.
a 10. Drop of Canada balsam and cover-glass.

SCHEME OF PREPARATION OF TISSUES BY PARAFFIN METHOD, TO BE STAINED IN SECTIONS.

1. Fix and wash if fixative requires it.
2. Dehydrate.
3. Xylol, turpentine, chloroform, or alcohol and cedar oil until translucent, one to twelve hours.
4. If chloroform has been chosen, into saturated solution of paraffin in chloroform. If alcohol and cedar oil, into pure cedar oil, for twelve hours in either case.
5. Into melted (50° C.) paraffin at 51° C. to 52° C. for from two to eight hours.
6. Cast, block, and trim it.
7. Cut sections and float out on warm (40° C.) water.
8. Fix sections to slide with Mayer's albumin and dry thoroughly for several hours on top of oven or in incubator at 37° C.

   Slides may be stored away and kept indefinitely at this stage. When wanted for use, proceed with:
9. Place slides in xylol, turpentine, or benzol, to dissolve off paraffin completely.
10. Place slides in absolute alcohol for five minutes, from which they can enter alcoholic stains. When aqueous stains are to be used, they are best placed for a minute in 85% alcohol first.

SCHEME OF PREPARATION OF TISSUES BY CELLOIDIN METHOD, TO BE STAINED IN SECTIONS.

1. Fix and wash if fixative requires it.
2. Dehydrate.
3. Alcohol and ether, twenty-four to forty-eight hours.
4. Thin celloidin, twenty-four hours.
5. Thick celloidin, forty-eight hours.
6. Block and allow to set.
7. Place blocks in chloroform or 85% alcohol for twenty-four hours.
8. Cut sections with knife wet with 85% alcohol.
9. Sections may be kept indefinitely in 85% alcohol until ready to be stained.

SCHEME FOR STAINING SECTIONS WITH BORAX CARMIN.

If celloidin sections are used, they may be transferred directly from one solution to the other with needles. If the paraffin sections are fixed to the side, either a few drops of the various solutions may be placed upon the section in the center of the slide or the whole slide may be immersed in a small jar of the solution, taking care to wipe off all excess of solution each time a change is made, in order to avoid contaminating the succeeding solutions.

1. Sections in borax carmin, half-hour.
2. Five per cent. HCl in 70% alcohol, from five to fifteen minutes, or until they become bright and light red.
3. Pure alcohol, which may contain a few crystals of picric acid, three minutes.
4. Xylol, creasote, or oil of cloves, which may also contain a little picric acid, three minutes.
5. Canada balsam and cover-glass.

SCHEME FOR STAINING SECTIONS WITH DELAFIELD'S HEMATOXYLIN AND EOSIN.

1. Section into Delafield's hematoxylin, from three to fifteen minutes.
2. Water, from three to five minutes.
3. One-half of 1% solution of eosin in 70% alcohol, two minutes.
4. Absolute alcohol, three minutes.
5. Creasote, xylol, or clove oil, three minutes.
6. Mount in Canada balsam and cover-glass.

SCHEME FOR STAINING SECTIONS IN ACID HEMATOXYLIN.

1. Section in Kulschitsky's hematoxylin, from five to fifteen minutes.
2. Rinse in water one minute.
3. Saturated aqueous solution of lithium carbonate until it becomes clear deep blue.
4. Absolute alcohol, three minutes.
5. Creasote, xylol, or clove oil, three minutes.
6. Mount in Canada balsam and cover-glass.

BLOOD EXAMINATION.

Fresh specimens of blood may be examined by simply placing a drop of blood on a slide and immediately covering it with a cover-glass. The slide and cover should be perfectly clean, in order that the drop may diffuse evenly between them. A $\frac{1}{6}$-inch objective is all that will be required to show the general characteristics of the red cells, the formation of rouleaux, etc., but for the demonstration of the granules in the leukocytes and to well observe the ameboid movement a $\frac{1}{12}$-inch oil-immersion lens will be required.

If it is desired to prolong the observation, it is well to seal up the mount by painting around the edge with melted paraffin, which will prevent evaporation.

The action of various reagents upon the cells may be watched by allowing a drop of the solution to diffuse slowly under the cover-glass from one corner, care being taken that none of the fluid is allowed to flow on the upper surface of the cover-glass.

Blood-platelets may be examined by placing a drop of a 1 % solution of osmic acid on the tip of the finger and pricking the finger through this, so that the blood in escaping shall flow directly into and mix with the acid. In this way the platelets are immediately fixed, and can then be examined under a cover-glass at leisure.

Fixed fluid preparations can be well made by allowing the blood to drop directly into Hayem's solution contained in a conical beaker. In twenty-four hours the red cells will be well fixed and will have settled to the bottom of the vessel. The fixing solution is now carefully poured off and water added, when the whole should be thoroughly stirred in order to wash the cells and rid them of any trace of the fixing solution. The cells are again allowed to settle, when some of them can be removed with a pipet and placed in a drop of glycerin on the slide and examined. The red cells are exceedingly well preserved by this method, but it is not suitable for studying the white cells.

Hayem's solution has the following formula:

Sodium chlorid	1	gm.
Sodium sulphate	5	"
Mercuric chlorid	0.5	"
Water	200	c.c.

At least one hundred times as much Hayem's solution as blood must be used.

After the cells have been fixed and washed, they may be stained in bulk by adding a little eosin to the water and allowing it to stand for a few hours, again pouring off the stain, adding fresh water, and allowing to settle.

Sections of the red cells may be obtained by ligating a small blood-vessel at both ends and then placing it in a fixing solution, from which it is treated the same as any ordinary tissue to be cut in paraffin. Thin sections should be cut, and may be stained with eosin with or without any of the nuclear stains.

Dried and **stained films,** however, give the most satisfactory pictures as permanent mounts. The spreads are made by taking two perfectly clean cover-glasses, touching the center of one of them to a small drop of blood, and immediately inverting it over the other in such a manner that the drop of blood is spread in a thin even layer between the two. The covers are then at once *slid* apart, taking care that no pressure is exerted upon them, as this would distort or destroy the cells. This will be most easily accomplished if the two covers are placed crosswise so that the corners of one project beyond the edges of the other. The spread should be as thin as possible, so that the cells may be well separated from one another.

After the spread has been made, it should be dried rapidly in air, when it is ready for one of the various methods of fixation.

Fixation.—In order to stain well, blood as well as other tissues requires to be fixed. For a study of the red cells an immersion of the dried film in alcohol or a mixture of equal parts of ether and alcohol for an hour is all that is required.

If the granules of the white cells are to be stained, the best fixative is heat. This is applied by placing the dried films in a small oven which is heated to 120° C. (248° F.) for twenty minutes and then allowed to cool gradually.

Staining.—The red cells stain well in a few minutes with the ordinary 0.5 % solution of eosin in 70 % alcohol. The specimen is then well rinsed in water, dried in air, and mounted with a drop of balsam. If it is desired to show the nuclei of the white cells as well, this staining may be preceded by a few minutes' immersion in either of the hematoxylin stains; or the two stains may be combined, as in the following formula of Gollasch:

Eosin (crystals)	0.5 gm.
Hematoxylin	2 "
Glycerin	
Absolute alcohol	āā 100 c.c.
Glacial acetic acid	10 "
Alum	slight excess.

After mixing, the solution should be kept in the sunlight as much as possible for a few weeks, when it will turn quite dark as it "ripens." When ready for use, it will stain spreads in from five to ten minutes, when the film should be well washed in water, dried in air, and mounted in balsam. If it is not desired to make a permanent preparation, however, the specimen, after rinsing, may be simply inverted upon a slide, the water removed from the upper surface by firmly blotting with a piece of filter-paper, and the specimen at once placed under the microscope. In case it should dry, another drop of water may be placed under the cover-glass and the examination continued.

With the foregoing mixture the red cells will be stained a coppery red, the eosinophile granules of the white cells a bright red, and the nuclei bluish.

The different types of white cells are best shown by Ehrlich's neutrophile mixture:

Saturated aqueous solution, orange G.	130 to 135	c.c.
Saturated aqueous solution, acid fuchsin	80 to 120	"
Saturated aqueous solution, methyl green	125	"
Distilled water	300	"
Absolute alcohol	200	"
Glycerin	100	"

Mix the orange G., acid fuchsin, water, and alcohol slowly in a bottle, shaking gently, and then add the methyl green and then the glycerin. The mixture should stand for several weeks before being used. Take the stain for use from the center of the bottle with a pipet, and avoid shaking or disturbing the solution any more than absolutely necessary.

To obtain the best results the smears should have been fixed by heat. Cover the spread with a few drops of the stain, and allow it to remain from three to fifteen minutes, according to the energy with which the stain acts; rinse the film rapidly in water, and examine it at once or allow it to dry thoroughly in air, and then mount in balsam. The red cells will be stained orange to brownish red, the nuclei light bluish, the eosinophile granules bright red, the neutrophile granules purplish.

The **eosinophile granules** may be intensely stained by covering the film with a saturated solution of eosin in glycerin and allowing it to remain for two hours, then rinsing in water, drying, and mounting in balsam.

The **basophile granules** may be stained by immersion in the following solution for two hours, rinsing in water, drying between filter-paper, and mounting in balsam:

Saturated solution of dahlia in glacial acetic acid	12.5 c.c.
Absolute alcohol	50 "
Distilled water	100 "

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